Chapter 3 - Barker Slough/North Bay Aqueduct

Potential Contaminant Source or Watershed Activity	Report Section	Water Quality Parameters							
		TDS/ Salts	Organic Carbon	Bromide	Pesticides	Nutrients	Pathogens	Trace Elements	Turbidity
Recreation	3.3.1	○	⊙		○	○	⊙	○	⊙
Wastewater Treatment/Facilities	3.3.2								
Urban Runoff	3.3.3	○	○	○	○	○	○	○	○
Animal Populations	3.3.4	○	●			◒	●	○	●
Agricultural Activities	3.3.5	○	◒		○	○		○	◒
Unauthorized Activities	3.3.6								
Geological Sources	3.4.4.3	○	●	○				⊙	●

Rating symbols:

● PCS is a highly significant threat to drinking water quality

◒ PCS is a medium threat to drinking water quality

⊙ PCS is a potential threat, but available information is inadequate to rate the threat

○ PCS is a minor threat to drinking water quality

Blank cells indicate PCS not a source of contaminant

Contents

Tables

Figures

3

Barker Slough/North Bay Aqueduct

The *Sanitary Survey Update Report 1996* concluded that the North Bay Aqueduct (NBA) had more water quality problems than any other component of the State Water Project (SWP). Contractors consistently list high total organic carbon (TOC), turbidities, and loss of alkalinity as their major challenges in treating NBA water. Based on the *Sanitary Survey 1996* findings, the Sanitary Survey Action Committee (SSAC) directed the Municipal Water Quality Investigations unit (MWQI) to conduct an in-depth study of the source water to the NBA. Since 1996, the Solano County Water Agency (SCWA), NBA contractors, and an independent consulting firm have worked with the California Department of Water Resources (DWR) to carry out this directive.

3.1 Watershed Description

SCWA field studies have determined the Barker Slough watershed is approximately 14.5 square miles (Figure 3-1). This is about half the 30 square-mile area reported in the *Sanitary Survey Update Report 1996*. Hydro Science, a consulting firm hired by the SCWA to develop Best Management Practice (BMP) options for the watershed, conducted the most recent surveys of the watershed. Although the exact boundary and area of the watershed require refinement, they are not expected to change dramatically.

The lower part of the watershed lies within the northwest section of the Sacramento-San Joaquin Delta (Figure 3-2). Less than 10% of the watershed is within the legal boundaries of the Delta. The watershed is bounded by the City of Vacaville to the west and the Jepson Prairie, University of California Natural Reserve to the southeast. The watershed has a Mediterranean climate, with the majority of the annual rainfall occurring in the winter. Average annual precipitation is 16 inches (DWR 1996). The Barker Slough Pumping Plant, near the terminus of Barker Slough, is the source of water for the NBA. Water is pumped from the slough via the NBA's pipeline and supporting structures to users in the north San Francisco Bay area.

In winter, the Barker Slough watershed is 1 of the dominant influences on water quality at the pumping plant (unpublished DWR data). In summer, water quality appears to be less influenced by the upstream watershed and more heavily influenced by local downstream inputs (DWR 1998).

Figure 3-1 Barker Slough Watershed and Land Use by Parcel as of Fall 2000

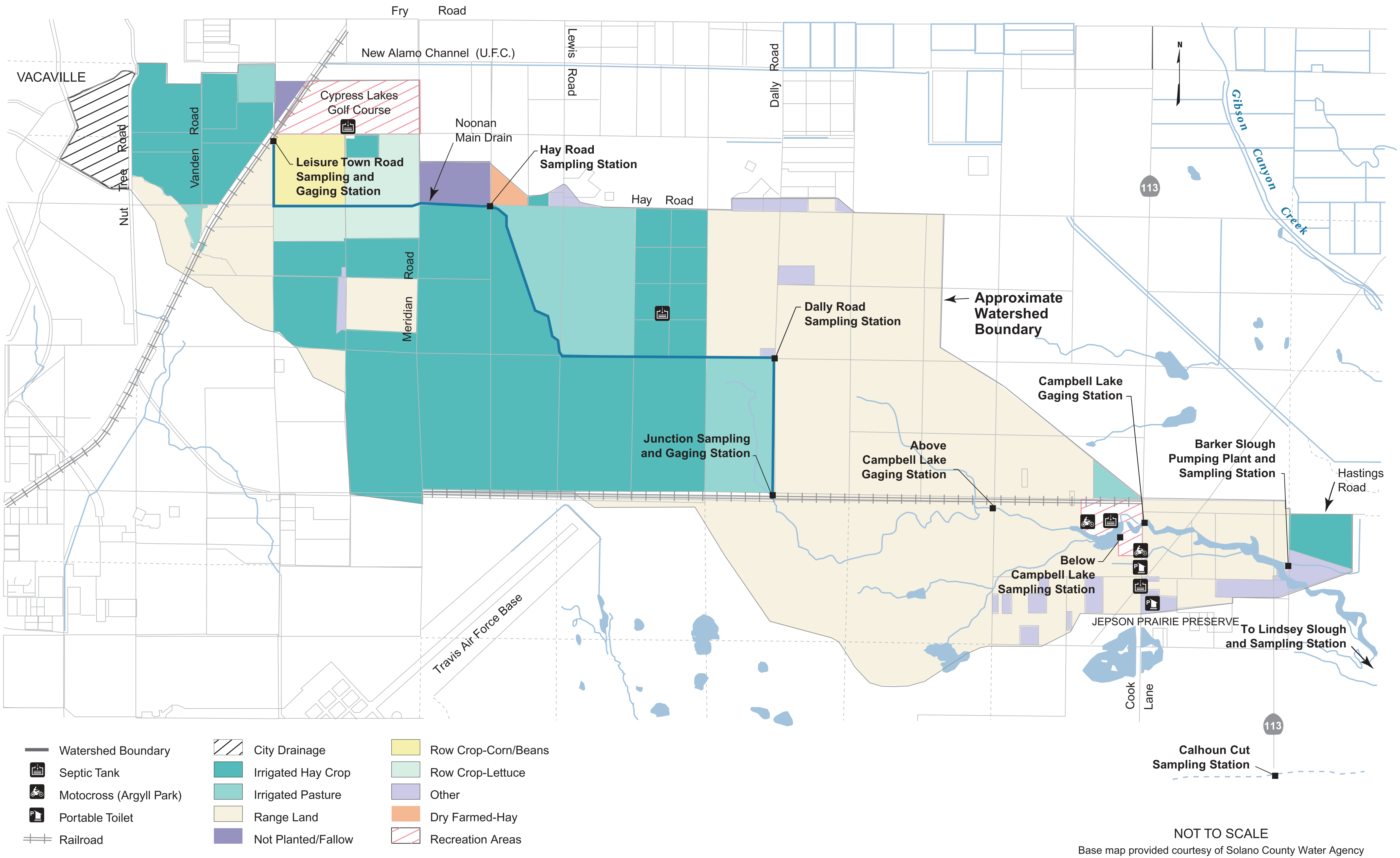
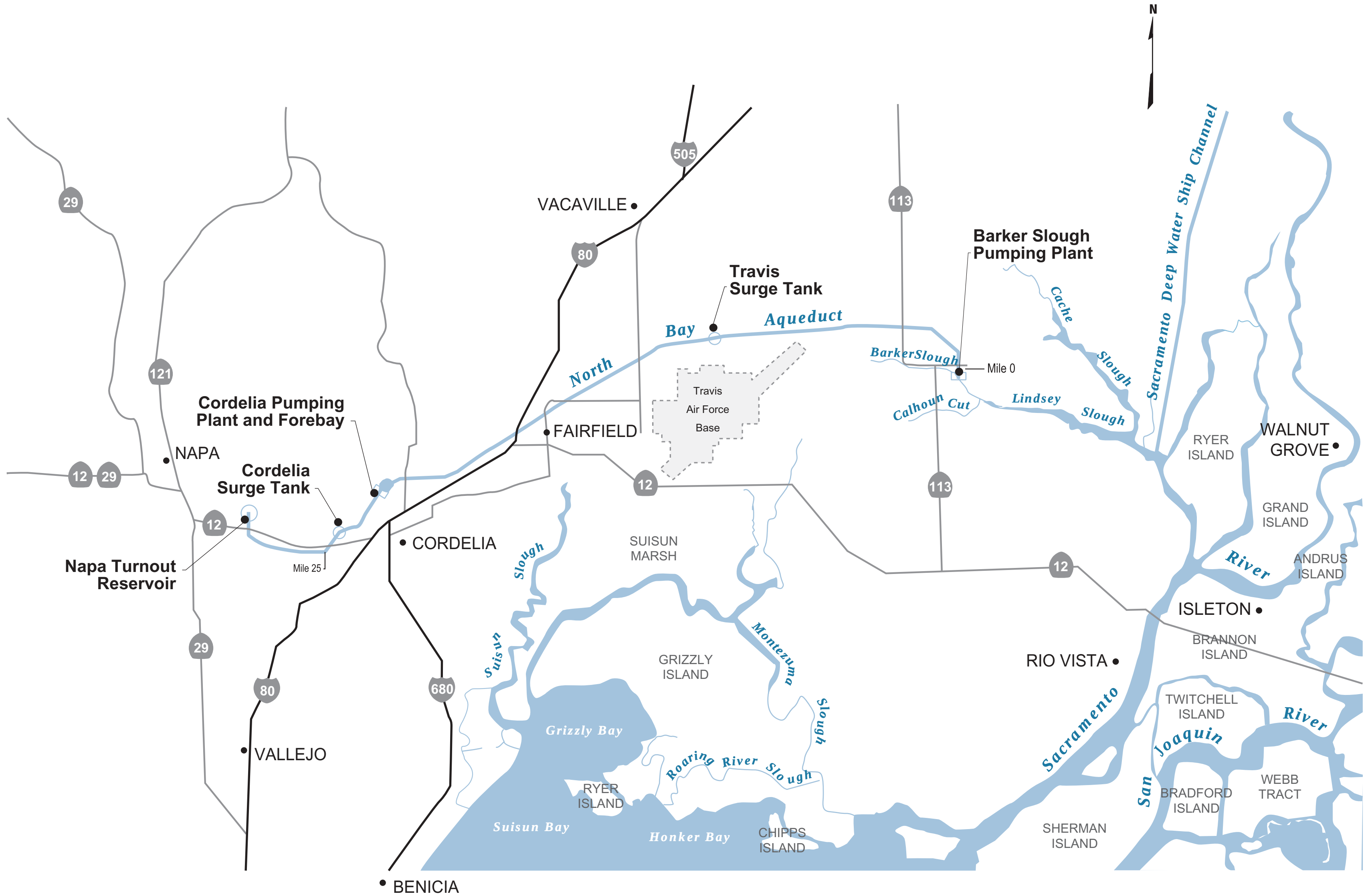


Figure 3-2 Location of the North Bay Aqueduct and Barker Slough Pumping Plant



0 2 4 Miles

Scale

Source: Department of Water Resources, Sacramento - San Joaquin Delta Atlas, 1993

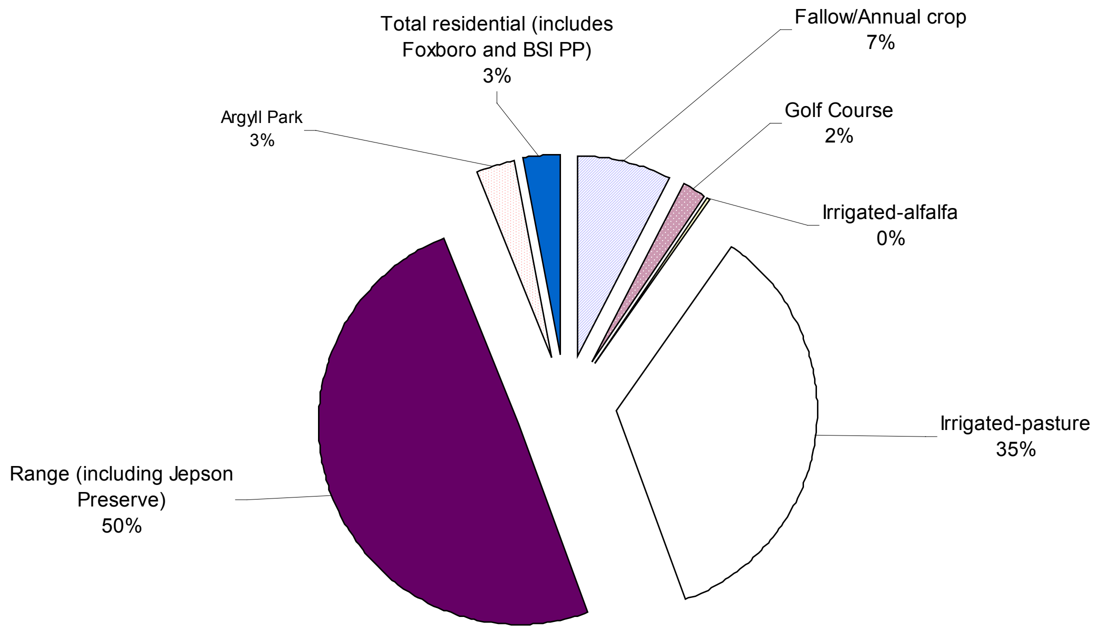
3.1.1 LAND USE

Land use within the Barker Slough watershed (primarily agricultural and divided between crop production and livestock grazing) has changed little since the *Sanitary Survey Update Report 1996* (Scribner pers. comm. 2000). The relatively poor soil conditions have restricted cultivated agriculture to the upper northwest corner of the watershed.

From 1996 to 1998, the California Department of Pesticide Regulation (DPR) documented pesticide use on alfalfa, sorghum, corn, and nursery stock within the watershed. DPR's database only documents crops that require the application of reportable pesticides. Primary exceptions to the full use reporting requirements are home and garden use and most industrial and institutional uses. Additionally, sugar beets, Sudan grass, and safflower have been observed growing in the upper watershed (DWR 1998).

Hydro Science (2000) completed the most recent land use survey of this watershed in fall 2000. Using observations and assessor parcel numbers, the firm divided acreage in the watershed into several land use categories. In at least 1 case—the small area of Vacaville's Foxboro subdivision—acreage is a rough estimate and could be subject to change. According to the survey, approximately 85% of the watershed's land use is rangeland and irrigated pasture (Figure 3-3). The remaining 15% is divided between annual crops and fallow land (7%), and urban and recreational uses (8%). Hydro Science's survey is proportionally similar to previous studies (DWR 1998).

Figure 3-3 Approximate Allocation of Land Use in the Barker Slough Watershed



The Solano County General Plan does not predict any land-use changes before 2010, the next scheduled general plan review. Both the general plan and county zoning designate most of the watershed area for agricultural use (Monske pers. comm. 2000). Although only a small part of its watershed is designated for urban development, Solano County is experiencing considerable growth pressure at its western agricultural boundaires from the City of Vacaville.

Storm drains from a small area in Vacaville's Foxboro subdivision flow into a channel that joins the Noonan Main Drain, a channelized portion of the slough maintained by Solano Irrigation District (SID). About 256 acres of the Foxboro subdivision lies within the Barker Slough watershed (McCall pers. comm. 2000). This represents about 2.5% of the watershed devoted to residential urban land use.

Recreational use includes Argyll Park, a 320-acre motocross track that has operated in the watershed since 1972 (Geier 1994). Argyll Park, which represents about 3% of land use in the watershed, is on Campbell Ranch and about 2 miles upstream of the pumping plant. Along the watershed’s upper northwest boundary is Cypress Lakes Golf Course, which makes up about 2% of the land use. With its docent-led tours in spring, the Jepson Prairie Preserve could be considered a recreational use. The Nature Conservancy transferred ownership of the preserve in 1997 to the Solano County Farmlands and Open Space Foundation. Research and educational use of the preserve is administered through UC Davis (Jepson 1998). About 490 acres of the preserve lie within the southeastern boundaries of the watershed.

3.1.2 Geology and Soils

The Barker Slough watershed, which is fairly uniform in surface geology, is in the Great Valley Geomorphic Province. In general, the watershed is partially filled with clay, silt, sand, and gravel deposited through millions of years of flooding. About 80% of the watershed is composed of alluvium, lake, playa, and terrace deposits, which are consolidated and semiconsolidated (California 1977). The western portion of the watershed contains both marine and nonmarine deposits in the Markley and Tehama Formations (California 1977). The ridge of the Markley Formation extends in a northwest to southeast direction and serves as the western boundary of the watershed. Although groundwater is found in all of the younger sediments, only the more permeable sand and gravel aquifers provide enough water to make wells feasible. These younger sediments overlie older marine sediments containing brackish or saline water (DWR 1998).

Soil units found in the watershed are the Antioch-San Ysidro complex, Capay clay loam, Pescadero clay loam, San Ysidro sandy loam, and Solano loam (Bates and others 1977). Except for the San Ysidro soil unit, these soils generally exhibit high soil pH. High soil pH can indicate high levels of sodium and other cations. These conditions create poor soils for agriculture (Singer 1999). With the exception of the Pescadero soil unit, all of the major soils within the watershed are within the "D" US Department of Agriculture's Hydrologic Soil group classification (Bates and others 1977). Pescadero is classified as a "C" soil group. Both soil types exhibit slow or very slow infiltration rates. Soils within the "D" classification are also characterized as heavy clay soils. The combination of high sodium, high clay, and moderate amounts of organic carbon contributes to the slow infiltration rates, the high runoff, and the potentially poor water quality observed in the slough (Singer 1999).

3.1.3 Vegetation and Wildlife

Where agricultural land uses are absent, the native vegetation has been classified as Valley Grassland, which includes dense to somewhat open bunch grass communities with forbs. Native perennial grasslands and vernal pools are examples of natural habitats native to the Central Valley of California and found in Jepson Prairie Preserve. The preserve has the highest density of vernal pools in Solano County (Barbor and Major 1977). The California Department of Fish and Game has designated vernal pool communities as significant natural communities and monitors their status through the Natural Heritage Program.

The preserve contains many rare and endangered plant and animal species. An inventory of Jepson Prairie flora can be found in the Jepson Prairie Preserve Handbook (Jepson 1998). Within the watershed, beaver and river otters have been observed. Burrowing owls have been observed in the upper reaches of the watershed in the banks of the Noonan Main Drain (Morris pers. comm. 2000).

3.1.4 Hydrology

Headwaters of the Barker Slough watershed begin on a small ridge near the outer edges of the City of Vacaville. The ridge delineates the western boundary of the watershed. Elevations range from 164 feet on some low hills in the southwest portion of the watershed to near sea level at the pumping plant. The average slope of the watershed is about 5 feet per mile toward the east or 0.01% (DWR 1996). Until it was channelized, the upper reaches of Barker Slough probably conveyed water only during winter rainfall months.

Storm drains from the Foxboro subdivision flow into an unnamed channel that probably is the old streambed of the slough. The channel runs through agricultural fields for approximately 2 miles before ending in the Noonan Main Drain (Figure 3-1). SID created this drain in 1961 when it channelized part of the upper portion of Barker Slough to deliver Lake Berryessa irrigation water to local landowners. As the Noonan Main Drain continues down the watershed, it joins the D-1-C spill extension. About half way down the watershed the Noonan Main Drain/D-1-C spill extension ends and continues as an unmaintained drain. This drain gives way to the old slough bed and continues east to a 40-acre impoundment on the Argyll Park property known as Campbell Lake. The combination of irrigation water and irrigation return water can cause the drain to flow for most of the year. However, the movement of irrigation return water out of Campbell Lake appears minimal. Flows in the drain normally drop dramatically in the fall following the end of water deliveries by SID and prior to the winter rainy season

The Campbell Lake dam was constructed for agricultural purposes and engineered by the US Department of Agriculture, Soil Conservation Service (Geier 1994). At the landowner's discretion, water is released through the removal of stacked boards that form the dam barrier. In winter, the boards are often removed to prevent flooding of the property. Although the slough is impounded behind a dam, a portion of it still flows out of Campbell Lake via a pipe with a valve control. Water through the pipe rejoins Barker Slough below the lake before continuing downstream to the pumping plant's forebay. Barker Slough and Calhoun Cut join about 1.5 miles downstream of the pumping plant at Lindsey Slough, which is about 6 miles long. Approximately a mile upstream of the Sacramento River Deep Water Ship Channel, Lindsey and Cache Slough merge. Cache Slough continues for another 2 to 3 miles before joining the Sacramento River.

The lower half of the watershed is prone to extensive flooding during winter months. During major storm events the lower reaches of the unmaintained drain and the slough routinely overtop their banks. Although no longer routinely monitored, DWR groundwater wells indicate that the perched water table is fairly close to the surface (DWR 1994). A shallow perched water table in combination with poorly infiltrated soils is probably a major contributor to seasonal flooding.

In addition to agricultural practices, rainfall, and a small part of the Foxboro subdivision, other sources of runoff are a golf course, uncultivated areas, active and abandoned rail lines, gravel, dirt, and paved roads, and the motocross recreation area.

3.2 WATER SUPPLY SYSTEM

3.2.1 DESCRIPTION OF AQUEDUCT/SWP FACILITIES

The NBA is a 27-mile long, pressurized, underground pipeline providing water to municipal and industrial users in Napa and Solano counties. The aqueduct was constructed in 2 phases. Phase I, built during 1967 and 1968, consisted of permanent and temporary structures. Permanent construction included the Cordelia Surge Tank, the Napa Turnout Reservoir, and a 4-mile long pipeline connecting them. In 1968, contractors began receiving water from Lake Berryessa via the Putah South Canal. Phase II, constructed from 1985 to 1988, extended the pipeline 23 miles from the Cordelia Surge Tank eastward to Barker Slough. The Barker Slough Pumping Plant then began delivering water to NBA contractors (DWR 1996a).

The pumping plant is on the north shore of Barker Slough about a half mile east of State Highway 113 (lat 38º16'534"N, long 121º55'93"W). Nine pumps with a design flow capacity of 224 cfs lift water from Barker Slough into the NBA (Gage pers. comm.). Upon completion of the pumping plant, a test showed a rated flow of 175 cfs (Gage pers. comm. 2000). To date, the maximum flow of the NBA is 142 cfs. Once in the NBA, water flows 9 miles downstream to the Travis Surge Tank. Water is delivered to Travis Air Force Base and to the Solano County communities of Fairfield and Vacaville via 2 turnouts. From the Travis Surge Tank, water flows by gravity to the Cordelia Forebay and Pumping Plant. At the Cordelia Forebay, there are 11 pumps and 3 transmission pipelines. Two of the 3 pipelines serve Benicia and Vallejo; the 3rd carries water to the Cordelia Surge Tank. Water continues from the surge tank through a 4-mile long pipe to the western terminus of the NBA, the Napa Turnout Reservoir. At the reservoir, 2 turnouts deliver water to the cities of American Canyon and Napa. The City of Napa delivers water to Yountville and Calistoga in Napa County.

3.2.2 DESCRIPTION OF AGENCIES USING SWP WATER

There are 2 SWP contractors for NBA water, the SCWA and the Napa County Flood Control and Water Conservation District (DWR 2000). These agencies provide water to a number of utilities. SCWA contracts with Travis Air Force Base and the cities of Benicia, Fairfield, Vacaville and Vallejo. The Napa County district contracts with the cities of American Canyon, Calistoga, Napa, and Yountville. The City of Napa provides treated water to Calistoga and Yountville. The North Bay Regional Water Treatment Plant (NBR WTP) in Fairfield provides treated water to Fairfield and Vacaville. From 1996 through 1999, only the City of Benicia, Travis Air Force Base, and Napa's Jameson Canyon Water Treatment Plant relied principally on NBA water. Depending on NBA water quality, availability, water rights, etc., some state contractors may blend NBA water or switch entirely to other sources.

A brief description of the utilities using NBA water follows. In some cases, storage and/or treatment plants may be shared among several municipalities. In these cases, municipalities were categorized under the municipality providing the storage service or the treated water. The percent of NBA water used by each municipality is shown in Table 3-1.

3.2.2.1 The City of Benicia

The NBA had been the primary source of water for Benicia, but from 1996 to 1999, the municipality occasionally blended NBA water with Lake Berryessa water transported via the Putah South Canal. Lake Berryessa water is of much higher quality and easier and less costly to treat. The Benicia Water Treatment Plant uses a conventional water treatment process involving alum/cationic polymer coagulation-flocculation, dual granular activated carbon (GAC)/sand gravel media filtration, and free chlorine disinfection. Caustic soda for pH adjustment controls corrosion, and fluoride is added for dental protection. The plant is rated hydraulically for 12 million gallons per day (mgd), but the typical annual rate ranges from 3 mgd to 10 mgd.

3.2.2.2 The City of Fairfield

Fairfield and Vacaville jointly own the NBR WTP, which has 2 raw water sources: the NBA and Lake Berryessa via the Putah South Canal. Depending on water quality, the NBR WTP may blend NBA water with Lake Berryessa water or use Lake Berryessa or NBA water exclusively. This flexibility is reflected in the percent of NBA water usage shown in Table 3-1. The NBR WTP's operating range is from 8 mgd to its design capacity of 40 mgd. In the summer, capacity can reach 34 mgd (Fleege pers. comm. 2000c). It uses ozone as the primary oxidant at a pre-ozone contact and has traditional coagulation/flocculation, sedimentation, and filtration. After deep-bed GAC filtration, the NBR WTP uses ozone for disinfection, caustic soda for pH adjustment, fluoride for dental protection, and free chlorine to disinfect the finished water. Like the Travis AFB Water Treatment Plant, the NBR WTP is 1 of the 1st recipients of NBA water.

3.2.2.3 The City of Napa

Napa operates 3 water treatment plants (WTPs): Jameson Canyon (for NBA water), and Hennessey and Milliken (for non-NBA water). The city rotates use of the treatment plants. Typically, the Jameson Canyon WTP operates from mid-November through March and is off-line the remainder of the year. The City of Napa sells treated water to the cities of Calistoga, Yountville, and American Canyon. NBA raw water is delivered from the Napa Turnout Reservoir and treated at the Jameson Canyon WTP, a conventional filtration plant with a capacity of 12 mgd (Walker pers. comm. 2000).

3.2.2.4 The City of American Canyon

American Canyon receives raw NBA water from the Napa Turnout Reservoir and treats it at a conventional treatment plant with a capacity of 2.6 mgd. The city also has interconnections to receive treated water from the City of Napa and the City of Vallejo (Walker pers. comm. 2000).

Table 3-1 Percent of North Bay Aqueduct Water Use Relative to Total Water Use by Each Municipality

	1996	1997	1998	1999
City of Benicia WTP	90	95	95	90
Jameson Canyon WTP-Napa County Flood Control and Water Conservation District	100	100	100	100
North Bay Regional WTP-Cities of Fairfield and Vacaville	54.1	59.1	47.3	56.9
Travis AFB WTP	100	100	100	100
Fleming Hill WTP-City of Vallejo	30	28	30	33

3.2.2.5 The City of Vallejo

The Fleming Hill Water Treatment Plant is the sole source of drinking water for the City of Vallejo. Typically, it treats a 70/30 blend of Lake Berryessa and NBA water, respectively. The WTP's capacity is 42 mgd. Its treatment train consists of: flow blending, pre-ozonation, flash and rapid mixing, flocculation, sedimentation, intermediate ozonation and GAC filtration. Gaseous chlorine is used for disinfection; sodium hydroxide is used for corrosion control; and fluoride is added for dental protection (Rice pers. comm. 2000).

3.2.2.6 Travis AFB WTP

The Travis AFB WTP, a 7-mgd conventional filtration plant with pre-ozone and GAC, is managed and operated by the City of Vallejo. The WTP relies solely on NBA water. The NBR WTP and the Travis AFB WTP are the 1st recipients of NBA water.

3.3 POTENTIAL CONTAMINANT SOURCES (PCSS)

3.3.1 RECREATION

There are 3 main recreational activities in the Barker Slough watershed:

- Argyll Park, a 320-acre multiuse recreational area in the southeastern corner of the watershed that is primarily used for motocross and go-kart racing;
- The Jepson Prairie Preserve, 1,556 acres near Argyll Park and managed by the Solano County Farmlands and Open Space Foundation; and
- Cypress Lakes Golf Course, 210 acres in the northern corner of the watershed and owned by Travis Air Force Base.

Argyll Park has a small concession stand, and some picnicking is allowed. Since the *Sanitary Survey Update 1996*, the only significant change at the park has been the redesign and improvement of its entrance as a condition of its use permit (Parker pers. comm. 2000). No new physical construction was allowed with the new permit except to mitigate for the existing go-kart track, where races occur on many weekends. It appears that motocross use has been declining (Parker pers. comm. 2000). The county does not have an inspection protocol to oversee permit terms (Parker pers. comm. 2000). The Dixon modelers club flies radio-controlled airplanes at Argyll Park and Campbell Lake, a 40-acre lake on the property, for sailing radio-controlled boats. Campbell Lake's primary use is to provide irrigation water for the owner. There is no body-contact recreation allowed in the lake.

At the Jepson Prairie Preserve, docent-led nature tours are conducted in the spring. Since 1983, the University of California, Davis, Natural Reserve System has been administering research and educational use at the preserve (Jepson 1998). Less than a third of the preserve (about 490 acres) lies within the watershed. Recreational activities at Jepson Prairie Preserve are designed to have a minimal impact and promote native vegetation. The impact of the preserve may have less to do with recreation and more to do with the preserve's soils, topography, and proximity to Barker Slough and Calhoun Cut.

From October 1999 to the end of September 2000, 47,000 visitors played a round of golf at the Cypress Lakes Golf Course (Joyce pers. comm. 2000). The golf course has been graded so that runoff enters the drainage ditch along Meridian Road (Joyce pers. comm. 2000). This drainage ditch joins the Noonan Main Drain and the unnamed drain receiving Foxboro runoff at the intersection of Fry and Meridian Roads. In addition to TOC and turbidity, runoff from the golf course could contain fertilizer or pesticides or both.

Activities at the Cypress Lakes Golf Course and the Jepson Prairie Preserve probably have little impact to the high TOC and turbidity levels. Runoff from the golf course may contribute slightly to the overall problem, but the course's area makes up less than 5% of the watershed and its vegetation potentially serves as a filter for runoff.

3.3.2 WASTEWATER TREATMENT/ FACILITIES

3.3.2.1 Septic Systems

Based on information from the Solano County Environmental Management Division, there are about 30 permitted septic systems in the Barker Slough watershed (Bell pers. comm. 2000). The highest concentration of septic systems is on the Box R Ranch. The number of septic system permits and approximate locations are listed in Table 3-2. Figure 3-1 shows approximate locations of septic systems with the exception of those on Hay and Dally Road. Hay and Dally roads also run outside of the watershed's boundaries. There was not enough information to determine if the septic systems were inside or outside the watershed. Although the county issues permits for septic systems, it does not have a water-quality monitoring program. The county would react to a system failure, but none have been reported (Schmidtbauer pers. comm. 2000).

Table 3-2 Location and Number of Permitted Septic Systems in the Barker Slough Watershed

Location	Permitted Septic Systems
Cypress Lakes Golf Course	4
Hay Road[a]	3
Box R Ranch[b]	8
Dally Road[a]	10
Argyll Park (Cook Lane)	2
Cook Lane	3

[a] Some sites may lie immediately outside watershed boundary.
[b] Approximately 1 mile east of Lewis Rd., cross street = Hay Road.

In the recreational areas, Argyll Park and the Jepson Prairie Preserve use chemical toilets for waste disposal. At the Cypress Lakes Golf course, 3 small septic systems are spread throughout the golf course and pumped out monthly. Two years ago, a 2,300-gallon septic system was added to the course and is also pumped out regularly. No leaks have occurred to any of the systems (Joyce pers. comm. 2000).

3.3.3 Urban Runoff

Preliminary loading calculations based on DWR special studies in the area suggest that urban runoff is not a large contributor to the TOC and turbidity problems experienced by the NBA contractors.

An estimated 256 acres of the City of Vacaville's Foxboro subdivision lie within the upper edge of the watershed (McCall pers. comm. 2000). Its storm drains empty into an unnamed channel that joins the Noonan Main Drain downstream. DWR field observations of the urban portion of the drain found that there is generally little measurable flow in the unnamed channel or the drain when SID is not delivering irrigation water. During winter storms, water levels in the upper section of the drain increase and decrease rapidly.

3.3.4 Animal Populations

3.3.4.1 Livestock Grazing

Grazing animals can contribute pathogens, TOC, nutrients, and increased turbidity resulting from erosion.

Both sheep and cattle graze in the Barker Slough watershed, but cattle comprise the bulk of farmed livestock. Generally, cattle are moved to the hills in spring to take advantage of green feed and moved back to the watershed in summer. The heaviest grazing occurs between November and June (DWR 1996). Although the time of calving has not been fully investigated, it appears to take place normally in the watershed during late summer. Calving also may occur in the hills. Calves have been observed in the watershed in December (Kimball pers. comm. 2000a). Cattle may be present in the watershed for 6 to 8 months of the year.

Fewer sheep are in the watershed, although their number is difficult to determine because they are present only 2 to 3 months of the year. Their shorter residence time is partly because their primary grazing lands are not found within the watershed (Kimball pers. comm. 2000a). As a rough estimate, the watershed may be able to support up to 1,500 sheep (Kimball pers. comm. 2000a).

Within the watershed, irrigated pasture supports approximately 1.25 to 1.3 cattle per acre; nonirrigated, dry rangeland supports less than 0.75 cattle per acre (Morris pers. comm. 2000). Preliminary calculations of potential stocking densities suggest the Barker Slough watershed could support from 2,600 to 2,700 animals annually (Kimball pers. comm. 2000b). These numbers were based on survey work conducted on 1 day in the fall; they tend to agree with UC Cooperative Extension stocking estimates that as many as 3,000 cattle use the watershed annually (Kimball pers. comm. 2000).

There is no known agency that tracks the number of sheep and cattle in township sections or on individual parcels (DaMassa pers. comm. 2000). The Solano County Department of Agriculture publishes an annual crop report that estimates the number of livestock farmed in the county.

Of the areas grazed in the watershed, only the Jepson Prairie Preserve has a range management plan (Morris pers. comm. 2000a). Management of the remaining acreage has not been fully investigated. Dead cows and sheep have been observed in and near the slough. At local meetings, ranchers have said it is too expensive to haul away dead animals. Generally, the slough is the only water source available for livestock. Fencing along much of the slough's length is either nonexistent or poorly maintained, allowing livestock access to the slough. The pumping plant is completely fenced to keep livestock away from the NBA intake. To DWR's knowledge, no studies have examined livestock access below the pumping plant.

3.3.5 Agricultural Activities

3.3.5.1 Pesticide/Herbicide Use

Using herbicides, SID controls vegetation on the banks of the Noonan Main Drain to remove or manage noxious plants such as yellow star thistle, tumbleweed, and fennel, while promoting the growth of grasses to decrease erosion. Weed management is also required for fire control and for maintenance and inspection of the drain. Algae in the drain is controlled to prevent it from clogging screens and slowing the flow. The district also controls rodents that could compromise bank integrity. Most contol measures occur between January and October. Personnel are certified by the State with Qualified Applicator Certificates and must undergo annual training on safety and pesticides application. Training is provided by a State-accredited, licensed pest control adviser. Chemicals used, the approximate period of application, their rate of application, and the reason for application is given in Table 3-3.

SID is phasing out its use of diuron in many locations (for example, along the inside banks of many drains including the Putah South Canal and Noonan Main Drain). The amount of pesticide is reduced substantially if clopyralid is substituted for diuron. The goal is to establish grasses on the sides of the banks that will screen out most of the star thistle. Star thistle will then be controlled by spot applications of herbicide (for example, using 2,4-D amine) (Vale pers. comm. 2000). Grass establishment along drains has been encouraging. After the 2nd year of practicing this form of weed control, grass has grown in some places to shield between 60% and 90% of the newly vegetated area.

SID has standard operating procedures for the application of pesticides. The type of pesticide (post- or pre-emergent) dictates the strategy the applicator must follow in relation to rainfall. Postemergent pesticides are not effective if washed off by rainfall; therefore, the applicator must take into account the time it takes for the pesticide to become "rain-fast," that is, no movement due to rainfall. Improper application of the herbicide defeats the purpose of its application and is costly to SID's weed control program. To ensure that postemergents are applied effectively and that they become rain-fast, SID uses the manufacturers' suggested rain-fast times (generally between 20 minutes and an hour) and applies a safety factor of no rainfall for a minimum of 2 to 4 hours after application (Vale pers. comm. 2000a).

With pre-emergents, a different application strategy is taken to minimize off-site movement due to rainfall. As with postemergents, the application of pre-emergents too soon after rainfall is costly and ineffective. Pre-emergents need to soak into the ground to be effective. Although they can be applied up to the time of rainfall, they are ineffective if the soil is saturated because they cannot penetrate. During the winter, SID generally waits 3 days after a rain event before applying pre-emergents. This allows time for the soil to dry so the pre-emergent can soak into the soil before the next rainfall. Also, application is normally delayed after a rainfall because applicators cannot drive the dirt roads for several days without damaging them. Approximately 90% of SID's access roads are dirt, and in winter, travel on them is reduced to prevent ruts and erosion problems (Vale pers. comm. 2000a).

Table 3-3 Pesticide Use by the Solano Irrigation District
(Post = Postemergent, Pre = Pre-emergent)

Pesticide (chemical name)	When applied	Rate applied	Reason for application
2,4-D amine (Post)	Jan–Apr	32 oz/acre	Broadleaf weed control
R-11 (Post)	As needed year round	64 oz/100 gal. of spray	Spreader-Activator
Aluminum phosphide	Feb–Mar	3-4 Tablets/burrow	Ground squirrel control
Copper Sulfate[a]	Apr–Oct	1-2 lbs/cfs	Algal control
Clopyralid (Mainly Pre)	Jan–Apr	4 to 8 oz/acre	Thistle control
Diuron (Pre)	Nov–Feb	8 lbs/acre	Pre-emergent weed control
Glyphosate (Roundup) (Post)	Usually Feb–Oct	48 oz/acre	Postemergent weed control and brush control.

Source: Mark Vale, Solano Irrigation District.
Pesticide is an umbrella term that includes insecticide, herbicide, and fungicide.
[a] Only applied during water deliveries

SID practices a conservative and responsible weed control program, but it is not known what standard operating procedures are followed for other herbicide applicators in the area. SID applicators have noted herbicide use on the railroad right of way near Leisure Town and along county roads. Weed control is also practiced on Highway 113 that runs through the watershed.

Pesticides and herbicides are used at the Cypress Lakes Golf Club for course maintenance. Round-up (glyphosate) is used for spot weeding. The most heavily applied compound is fertilizer or a fertilizer pre-emergent product. Fairways are normally fertilized 3 to 4 times a year (Goldbronn pers. comm. 2000). Up to 10,000 pounds per application are allowed, although this is the high end of usage. Annually, the 1st application of fertilizer occurs in mid to late February. Application depends on the weather. No compound is applied if the ground is too wet to support a tractor. The last application of fertilizer generally occurs in early November. Depending on weather conditions, fungicide is applied 2 times between August and December but only to the putting greens. The type of fungicide and its application are tied to the weather because different conditions promote the growth of different funguses.

From 1996 through 1998, pesticide use in Solano County remained fairly constant, varying between 1.7 million and 2 million pounds (DPR 1996, 1997, 1998). Within the Barker Slough watershed, irrigated agriculture primarily occurs in the upper half of the watershed. Table 3-4 lists the pounds of active ingredients of all reportable pesticides applied to the upper half of the watershed from 1996 through 1998 (most recent year data were available) (Bartkowiak pers. comm. 2000). During this period, reportable pesticides were applied to alfalfa, sorghum, corn, and nursery stock. Township 06 N Range 01 W Section 36 also reflects compounds applied at Cypress Lakes Golf Club. As noted in Section 3.1.1, Land Use, sugar beets, Sudan grass, and safflower have been previously observed growing in this area of the watershed. Sugar beet crop, along with tomato processing and canning, grapes, and pears, was 1 of the top 5 commodity users of pesticides countywide in 1998 (only year data were available) (DPR 1998). Because of market influences, sugar beets may be farmed less in the future; therefore, the crop’s future in Barker Slough watershed may be limited. The top 5 pesticides applied to sugar beets in 1998 were methyl-bromide, metam-sodium, glyphosate, paraquat dichloride, and ammonium sulfate (DPR 1998). Of these substances, DWR monitors for ammonia, glyphosate, and sulfate.

Table 3-4 Pesticide Application, by Crop, (lbs of Active Ingredient) for Upper Section of the Barker Slough Watershed, 1996-1998

TRS	Chemical	Year 1996	1997	1998	Crop
05N01 E05	PETROLEUM HYDROCARBONS	38.44	38.44	38.44	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	PARAQUAT DICHLORIDE	24.04	24.04	24.04	"
	CHLORPYRIFOS	18.53	18.53	18.53	"
	ALKYL OXY-POLYOXYETHYLENE AND ALKYL PHENYLOXY-POLYOXYETHYLENE	9.71	9.71	9.71	"
	PHOSPHORIC ACID	0.36	0.36	0.36	"
	PROPYLENE GLYCOL	0.26	0.26	0.26	"
	TRISODIUM PHOSPHATE	0.11	0.11	0.11	"
	Total	**91.45**	**91.45**	**91.45**	
05N01 E06	CARBARYL	1,197.80	1,197.80	1,197.80	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	OCTYL PHENOXY POLY ETHOXY ETHANOL	69.97	69.97	69.97	"
	METHOMYL	58.76	58.76	58.76	"
	ISOPROPYL ALCOHOL	12.84	12.84	12.84	"
	CITRIC ACID	7.14	7.14	7.14	"
	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	6.56	6.56	6.56	"
	COMPOUNDED SILICONE	3.43	3.43	3.43	"
	PYRETHRINS	1.99	1.99	1.99	"
	ROTENONE, OTHER RELATED	1.66	1.66	1.66	"
	ROTENONE	1.66	1.66	1.66	"
	CALCIUM CHLORIDE	0.86	0.86	0.86	"
	Total	**1,362.66**	**1,362.66**	**1,362.66**	
05N01 E07	CARBARYL	1,026.86	1,026.86	1,026.86	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	METHOMYL	96.27	96.27	96.27	"
	CITRIC ACID	12.41	12.41	12.41	"
	ISOPROPYL ALCOHOL	11.51	11.51	11.51	"
	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	11.40	11.40	11.40	"
	CALCIUM CHLORIDE	1.49	1.49	1.49	"
	Total	**1,159.95**	**1,159.95**	**1,159.95**	
05N01 E08	CARBARYL	538.04	538.04	538.04	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	METHOMYL	60.03	60.03	60.03	"
	CITRIC ACID	45.65	45.65	45.65	"
	ISOPROPYL ALCOHOL	42.38	42.38	42.38	"
	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	41.96	41.96	41.96	"
	CALCIUM CHLORIDE	5.48	5.48	5.48	"
	Total	**733.53**	**733.53**	**733.53**	

Table 3-4 (continued)

TRS	Chemical	Year 1996	Year 1997	Year 1998	Crop
05N01 W01	CARBARYL	95.94	95.94	95.94	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	CARBARYL	75.08	75.08	75.08	CORN (FORAGE - FODDER)
	METOLACHLOR	59.38	59.38	59.38	CORN (FORAGE - FODDER)
	OCTYL PHENOXY POLY ETHOXY ETHANOL	10.00	10.00	10.00	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	PHOSPHORIC ACID	1.43	1.43	1.43	CORN (FORAGE - FODDER)
	PROPYLENE GLYCOL	1.05	1.05	1.05	CORN (FORAGE - FODDER)
	ISOPROPYL ALCOHOL	0.89	0.89	0.89	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	COMPOUNDED SILICONE	0.49	0.49	0.49	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)
	TRISODIUM PHOSPHATE	0.45	0.45	0.45	CORN (FORAGE - FODDER)
	Total	**244.70**	**244.70**	**244.70**	
06N01 W35	PETROLEUM HYDROCARBONS	109.17	109.17	109.17	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	PARAQUAT DICHLORIDE	68.27	68.27	68.27	"
	ALKYL OXY-POLYOXYETHYLENE AND ALKYL PHENYLOXY-POLYOXYETHYLENE	27.56	27.56	27.56	"
	CHLORPYRIFOS	13.14	13.14	13.14	"
	PHOSPHORIC ACID	0.34	0.34	0.34	"
	PROPYLENE GLYCOL	0.25	0.25	0.25	"
	TRISODIUM PHOSPHATE	0.11	0.11	0.11	"
	Total	**218.84**	**218.84**	**218.84**	
06N01 W36	FOSETYL-AL	1,528.03	1,528.03	1,528.03	N-OUTDR CONTAINER/FLD GRWN PLANTS
	MANCOZEB	905.74	863.74	905.74	"
	THIOPHANATE-METHYL	883.20	872.00	672.22	"
	PETROLEUM DISTILLATES, REFINED	867.03	867.03	867.03	"
	ORYZALIN	442.24	432.59	442.24	"
	PCNB	330.42	330.42	330.42	"
	POLY-I-PARA-MENTHENE	291.76	288.27	291.76	"
	OXYFLUORFEN	274.19	274.19	274.19	"
	NAPROPAMIDE	251.13	251.13	251.13	"
06N01 W36	PENDIMETHALIN	204.18	204.18	204.18	"
	COPPER HYDROXIDE	165.31	151.14	165.31	"
	IPRODIONE	163.75	163.75	163.75	"
	ACEPHATE	161.84	160.15	104.09	"
	2-(3-HYDROXYPROPYL)-HEPTA-METHYL TRISILOXANE, ETHOXYLATED, ACETATE	97.82	95.84	97.82	"
	OXADIAZON	85.95	85.95	85.95	"
	METALDEHYDE	64.80	64.80	64.80	"

Table 3-4 (continued)

TRS	Chemical	Year 1996	1997	1998	Crop
	ISOXABEN	47.11	46.95	47.11	"
	CHLOROTHALONIL	46.16	46.16	46.16	"
	METALAXYL	38.50	38.50	11.20	"
	DIAZINON	34.97	34.97	34.97	"
	MALATHION	33.37	33.37	33.37	"
	CARBOFURAN	29.99	29.99	29.99	"
	PHOSPHORIC ACID	14.89	14.89	14.89	"
	CHLORPYRIFOS	14.42	14.42	14.42	"
	BENDIOCARB	13.21	13.21	13.21	"
	CHLORPYRIFOS	12.52	12.52	12.52	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	PROPICONAZOLE	7.54	7.54	7.54	N-OUTDR CONTAINER/FLD GRWN PLANTS
	MANGANESE SULFATE	5.35	5.35	5.35	N-OUTDR CONTAINER/FLD GRWN PLANTS
	PIPERONYL BUTOXIDE	5.17	5.17	5.17	"
	POLYOXYETHYLENE POLYMER	3.52	3.52	3.52	"
	MYCLOBUTANIL	3.48	3.48	3.48	"
	OXYTHIOQUINOX	3.12	3.12	3.12	"
	STREPTOMYCIN SULFATE	3.07	3.07	3.07	"
	COPPER SULFATE (PENTAHYDRATE)	3.03	3.03	3.03	"
	CYFLUTHRIN	2.27	2.27	2.27	"
	TRIADIMEFON	1.89	1.89	1.89	"
	BACILLUS THURINGIENSIS (BERLINER), SUBSP. ISRAELENSIS, SEROTYPE H-14	1.85	1.85	1.85	"
	PIPERONYL BUTOXIDE, TECHNICAL, OTHER RELATED	1.29	1.29	1.29	"
	DIENOCHLOR	0.75	0.75	0.75	"
	ZINC SULFATE	-	0.69	0.69	"
	OCTYL PHENOXY POLY ETHOXY ETHANOL	0.67	0.67	0.67	"
	PYRETHRINS	0.65	0.65	0.65	"
	DODECYLBENZENE SULFONIC ACID	0.57	0.57	0.57	"
	1,3-DICHLOROPROPENE	0.39	0.39	0.39	"
	AVERMECTIN	0.26	0.26	0.26	"
	PHOSPHORIC ACID	0.24	0.24	0.24	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	TRIETHANOLAMINE	0.22	0.22	0.22	N-OUTDR CONTAINER/FLD GRWN PLANTS
	PROPYLENE GLYCOL	0.18	0.18	0.18	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	SODIUM XYLENE SULFONATE	0.18	0.18	0.18	N-OUTDR CONTAINER/FLD GRWN PLANTS
	ISOPROPYL ALCOHOL	0.17	0.17	0.17	"
	DIETHYLAMINE SALT OF COCONUT FATTY ACID	0.13	0.13	0.13	"

Table 3-4 (continued)

TRS	Chemical	1996	1997	1998	Crop
	TETRAPOTASSIUM PYROPHOSPHATE	0.09	0.09	0.09	"
	CHLOROPICRIN	0.08	0.08	0.08	"
	TRISODIUM PHOSPHATE	0.08	0.08	0.08	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)
	3,7,11-TRIMETHYL-2,6,10-DODECATRIENE-1-OL	0.04	0.04	0.04	N-OUTDR CONTAINER/FLD GRWN PLANTS
	EDTA, TETRASODIUM SALT	0.04	0.04	0.04	"
	3,7,11-TRIMETHYL-1,6,10-DODECATRIENE-3-OL	0.03	0.03	0.03	"
	BACILLUS THURINGIENSIS (BERLINER), SUBSP. KURSTAKI, SEROTYPE 3A,3B	0.02	0.02	0.02	"
	TAU-FLUVALINATE	0.02	0.02	0.02	"
	ALKYLARYL POLY(OXYETHYLENE) GLYCOL	0.02	0.02	0.02	"
	SILICONE DEFOAMER	0.01	0.01	0.01	"
	DIPHACINONE	0.002	0.002	0.002	"
	Total	**7,048.95**	**6,965.31**	**6,753.60**	

Source: Donna Bartkowski, Department of Pesticide Regulation

3.3.6 Unauthorized Activity

3.3.6.1 Spills/Illegal Dumping

There are generally no records of illegal dumping or spills in the unincorporated area of the watershed (Eubank pers. comm. 2000).

3.3.6.2 Underground Storage Tanks

The Solano County Division of Environmental Management has no record of any leaking underground storage tanks in the watershed (Eubank pers. comm. 2000). More accurate estimates of the watershed's boundaries have excluded many of the underground storage tanks identified in the *Sanitary Survey Update 1996* (for example, Travis Air Force Base).

3.4 Water Quality Summary

3.4.1 Watershed (Barker Slough Pumping Plant)

In this section, comparisons are made between contaminant concentrations in SWP source water and maximum contaminant levels (MCLs) for finished drinking water. Although MCLs are usually applied to finished water, they are useful as conservative indicators of contaminants that concern utilities and that require removal during the treatment process to meet finished water standards. Comparisons also serve to focus on particular PCSs associated with contaminants of concern and to develop appropriate recommendations for actions. It follows that if source water concentrations are below MCLs, then these contaminants are not likely to be of concern to the finished water supplies.

Since 1987, DWR's Operations and Maintenance Division (O&M) has routinely conducted monthly monitoring for organic, inorganic, and miscellaneous compounds at the Barker Slough Pumping Plant. From 1996 through 1999, all conventional parameters and major minerals in the O&M samples were below MCLs for finished drinking water or Article 19 objectives (DWR 1999, 2000a). Conventional parameters include conductivity, hardness, lab pH, suspended solids, suspended volatile solids, field temperature, total dissolved solids, and turbidity. Major minerals include the cations calcium, magnesium, and sodium, and the anions bicarbonate (alkalinity), chloride, nitrate, and sulfate. Selected conventional parameters and major minerals are shown in Table 3-5. Even at its lowest level, turbidity was above the secondary MCL of 5 NTUs. Turbidity patterns are discussed in detail in Section 3.3.3, Key Constituents of Concern to NBA Contractors.

Minor elements include metals such as copper, zinc, and iron, and nonmetals such as arsenic and selenium. They are called minor elements because concentrations are usually below 1 part per million in natural surface waters. From 1996 through 1999, dissolved aluminum, iron, and manganese were detected above primary or secondary MCLs. These metals are discussed further in Section 3.3.2.1, Title 22 Constituents. The remaining minor elements were below the MCLs for finished drinking water or Article 19 objectives (DWR 1999, 2000a).

Table 3-5 Barker Slough Pumping Plant, Jan 1996 to Dec 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Minerals							
Calcium	16	16	7	26	9.0 - 22	1.0	51/51
Chloride	21	18	6	47	10.0- 36	1.0	51/51
Total Dissolved Solids	183	176	90	300	126 - 262	1.0	51/51
Hardness (as CaCO3)	97	95	46	162	56 - 146	1.0	51/51
Alkalinity (as CaCO3)	101	101	37	167	63 - 139	1.0	83/83
Conductivity	312	303	126	501	186 - 460	1.0	52/52
Magnesium	14	14	7	24	8.0 - 21	1.0	51/51
Sulfate	24	20	5	53	9.0 - 44	1.0	51/51
Turbidity (NTU)	65	45	18	256	23 - 157	1.0	106/106
Minor Elements (dissolved) (mg/L)							
Aluminum	0.02	0.01	< 0.01	0.438	0.01 - 0.011	0.01	12/81
Arsenic	0.00	0.002	0.001	0.004	0.002 - 0.003	0.001	49/49
Barium	0.05	0.05	< 0.05	0.08	0.05 - 0.06	0.05	14/48
Boron	0.21	0.2	0.1	0.4	< 0.1 - 0.38	0.1	48/51
Chromium	0.01	0.005	< 0.005	0.011	0.005 - 0.007	0.005	18/49
Copper	0.004	0.004	0.005	0.005	0.002 - 0.005	0.001	31/49
Managanese	0.03	0.019	< 0.005	0.358	0.008 - 0.044	0.005	78/81
Zinc	0.01	0.005	< 0.005	0.05	0.005 - 0.05	0.005	5/48
Nutrients (mg/L)							
Total ammonia	0.95	0.7	0.4	2	0.5 - 1.72	0.01	29/29
Total Kjeldahl Nitrogen(as N)	0.9	0.7	0.4	2	0.5 - 1.7	0.1	29/29
Nitrate (as NO3)	0.4	0.4	0.4	0.4	0.4 - 0.4	0.1	1/1
Nitrate+Nitrite (as N)	0.38	0.3	0.08	3.5	0.13 - 0.53	0.01	50/50
Total Phosphorus	0.23	0.21	0.1	0.43	0.15 - 0.35	0.01	51/51
Orthophosphate	0.09	0.1	0.01	0.15	0.07 - 0.12	0.01	51/51
Misc.							
Bromide (mg/L)	0.05	0.04	0.01	0.10	0.02 - 0.08	0.01	51/51
Total Organic Carbon (mg/L)	7.2	5.6	1.0	38.0	2.9 - 13.6	0.1	117/117
pH (pH unit)	7.5	7.6	6.9	8.2	7.1 - 8	0.1	21/21
UVA (uS/cm)	0.462	0.328	0.112	0.99	0.121 - 0.952	0.001	20/20

Source: DWR O&M Division database, May 2000
Notes: All metals Jan 1996 through Dec 1999.
Turbidity data from Jun 1996 through Dec 1999.
Total Kjeldahl Nitrogen(as N) and total ammonia data collected from Jun 1996 through Mar 1998.
Only one sample collected for Nitrate. All other nutrient data from Jan 1996 through Dec 1999.
Bromide and TOC data from Jan 1996 through Dec 1999.
pH and UVA data from Feb 1998 through Dec 1999.

Nutrients enhance plant growth in surface waters and include nitrogen and phosphorus compounds. Primary MCLs exist for nitrite and nitrate as nitrogen as well as nitrate and nitrite as nitrogen. No standards or objectives exist for the other nutrients. Concentrations for selected nutrients monitored by O&M from 1996 through 1999 are shown in Table 3-5. Nutrient levels were below all MCLs for finished drinking water. In 1996 and 1997, O&M examined seasonal nutrient trends. Although data were not extensive, nitrogen compounds flucuated seasonally and increased during periods of rainfall (DWR 1999). Additionally, organic nitrogen was correlated with TOC, while nitrate was not. By definition, organic nitrogen is organically bound to compounds such as proteins, peptides, nucleic acids, urea, and other organics present in animal fecal material. In contrast, nitrates in surface water can originate from a number of sources including animal waste, fertilizers, and nitrification. Nitrates are also more likely than organic nitrogen to percolate through soil, reducing the amount available for transport via runoff.

O&M monitors pesticides and organic chemicals at the pumping plant 3 times a year, usually in March, June, and October (DWR 1999). Samples are analyzed for chlorinated organics, chlorinated phenoxy acid herbicides, glyphosate, volatile organics (including MTBE), and carbamates (DWR 2000a). From 1995 to 1999, the MWQI unit has analyzed Barker Slough Pumping Plant samples for pesticides 12 times. Samples were collected in December 1995, March and June 1996, twice in September 1996, October 1996, twice in December 1996, twice in March 1997, once in June 1997, and again in June 1999.

Based on DPR data, Table 3-6 lists the top 2 pesticides applied in terms of pounds within the township-ranges encompassing areas of the upper Barker Slough watershed. Table 3-7 shows pesticide concentrations at the Barker Slough Pumping Plant of pesticides that were either applied by SID or were 1 of the top 2 pesticides applied in the upper watershed, according to DPR use reports. Of DPR-reported compounds, DWR monitors for carbaryl and methomyl. Neither was detected 1996 through 1999. With respect to the compounds applied by SID, DWR monitors for 2,4-D, aluminum, copper, diuron, glyphosate, and sulfate. Of the organic pesticides applied by SID, only diuron has been detected. Diuron concentrations ranged from below the detection limit to 4.24 μg/L. There is no MCL for this compound.

Table 3-6 Top 2 Pesticides (in Terms of lbs) Applied in Townships, Ranges, and Sections Encompassing Irrigated Lands in the Upper Barker Slough Watershed, 1996 to

Township, Range, Section	Top 2 pesticides applied (as lbs) from 1996-1998	Pounds Applied	Crop Application
05N01E05	PETROLEUM HYDROCARBONS	38.44[a]	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)[b]
	PARAQUAT DICHLORIDE	24.04[a]	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)[b]
05N01E06	CARBARYL	1197.8[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
	OCTYL PHENOXY POLY ETHOXY ETHANOL	69.97[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
05N01E07	CARBARYL	1026.86[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
	METHOMYL	96.27[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
05N01E08	CARBARYL	538.04[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
	METHOMYL	60.03[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
05N01W01	CARBARYL	95.94[a]	SORGHUM (FORAGE - FODDER) (SORGO, ETC.)[b]
	CARBARYL	75.08[a]	CORN (FORAGE - FODDER)[b]
06N01W35	PETROLEUM HYDROCARBONS	109.17[a]	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)[b]
	PARAQUAT DICHLORIDE	68.27[a]	ALFALFA (FORAGE - FODDER) (ALFALFA HAY)[b]
06N01W36	FOSETYL-AL	1528.03[a]	N-OUTDR CONTAINER/FLD GRWN PLANTS[b]
	MANCOZEB	905.74[c]	N-OUTDR CONTAINER/FLD GRWN PLANTS[d]
	THIOPHANATE-METHYL	872.00[e]	N-OUTDR CONTAINER/FLD GRWN PLANTS

Information provided courtsey of Donna Bartkowiak, Department of Pesticide Regulation
[a] Same number of pounds applied in 1996, 1997, and 1998
[b] Applied to same crop in 1996, 1997, and 1998
[c] Only applied in 1996 and 1998. Same number of pounds applied in both years.
[d] Applied to same crop in 1996 and 1998
[e] One of 2 of the top pesticides used in 1997

Table 3-7 Selected Pesticides Detected at the Barker Slough Pumping Plant, 1996 to [a]

		MWQI		O & M	
	MCL	mean	range	mean	range
2,4-D (μg/L)	70	< 0.1		< 0.1	
Carbaryl (μg/L)	-	< 2		< 2	
Diuron (μg/L)	-	0.89	< 0.25 - 4.24	0.26	< 0.25 - 0.26
Glyphospate (μg/L)	700	< 100		< 100	
Methomyl (μg/L)	-	< 2		< 2	

[a] Pesticides were either applied by SID or, based on DPR use reports, were 1 of the top 2 pesticides applied in upper watershed.

With respect to individual constituents of inorganic pesticides, monthly samples for dissolved copper as well as sulfate concentrations were below MCL or Article 19 objectives (DWR 1999, 2000a). According to quarterly Title 22 analyses, total copper has consistently been below the detection limit, but concentrations of total aluminum are routinely detected above its primary MCL (DeAlbidress pers.

comm. 2000). Aluminum is discussed in Section 3.3.2.1, Title 22 Constituents. Finally, of the 962 pesticide analyses conducted by MWQI, only 6 pesticides have been detected from 1996 through 1999 (Table 3-8). With the exception of simazine, no MCLs have been established for any of these pesticides. All simazine detections were below the MCL.

Table 3-8 Pesticides Detected at the Barker Slough Pumping Pumping Plant from MWQI Studies

Pesticide	Sample Date	MCL	Result (µg/L)
bis(2-Ethylhexyl) phthalate	9/5/96	-	4.0
Diazinon	9/30/96	-	.01
Diazinon	9/30/96		.05
Diazinon	12/30/96		.01
Diuron	12/30/96	-	.75
Diuron	3/31/97		4.24
Formetanate hydrochloride	6/6/96	-	100
Methidathion	6/16/97	-	.07
Simazine	3/7/96	4	1.3
Simazine	12/30/96		.62
Simazine	3/31/97		.14

Note: Samples collected Dec 1995 and quarterly in 1996. Samples also collected in Mar 1997, Jun 1997, and Jun 1999

Bromide concentrations at the Barker Slough Pumping Plant from 1996 to 1999 ranged from 0.1 to 0.95 mg/L and averaged 0.46 mg/L (Table 3-5). These concentrations were frequently above the 0.05 mg/L level desired by utilities. Unlike organic carbon, bromide concentrations do not increase during the rainy season, instead increases are usually observed during spring and early summer (Figure 3-4) (DWR 1998, 1999, 2000a).

At Lindsey Slough, which is closer to the Sacramento River, bromide concentrations reflect seawater intrusion. In the absence of other sources, bromide concentrations at Lindsey Slough should be the same or higher than bromide concentrations upstream at the pumping plant. However, comparisons between samples collected at Lindsey Slough and the Barker Slough Pumping Plant show bromide concentrations at the pumping plant are the same or higher than bromide concentrations downstream at Lindsey Slough (Figure 3-5). Bromide concentrations between the 2 sites are also significantly different (one-tailed t-test, $p < 0.05$); samples were not necessarily collected at high tide at either sampling point.

With these caveats, 1 hypothesis for these results may be the movement of bromide by groundwater. Because groundwater movement will be much slower than surface runoff, groundwater impacts may not occur until after the rainy season. Within the watershed, the Markley Formation may contain ancient marine sediments, which could leach bromide into the groundwater. Another hypothesis is that the evaporation of irrigation water could create a buildup of salts, including bromide (DWR 1998). No formal studies have been conducted to verify either of these hypotheses.

Figure 3-4 Average Monthly Bromide Concentration (mg/L) at the Barker Slough Pumping Plant, 1996 to 1999

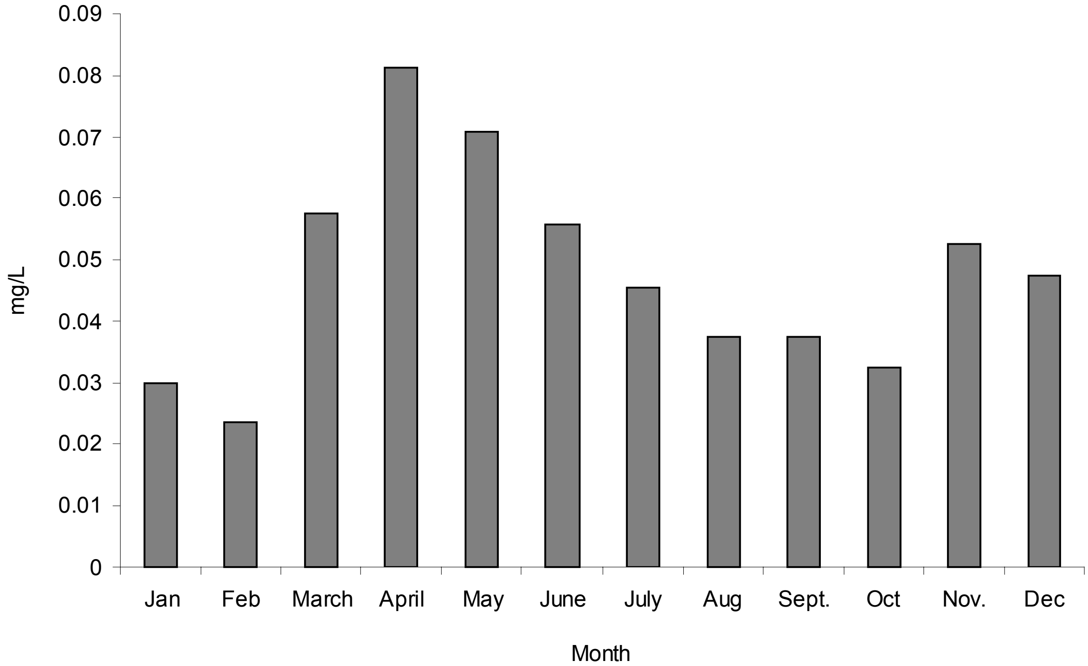


Figure 3-5 Comparison of Bromide Concentrations between the Barker Slough Pumping Plant and Lindsey Slough, Jun 1996 to Jul 1997

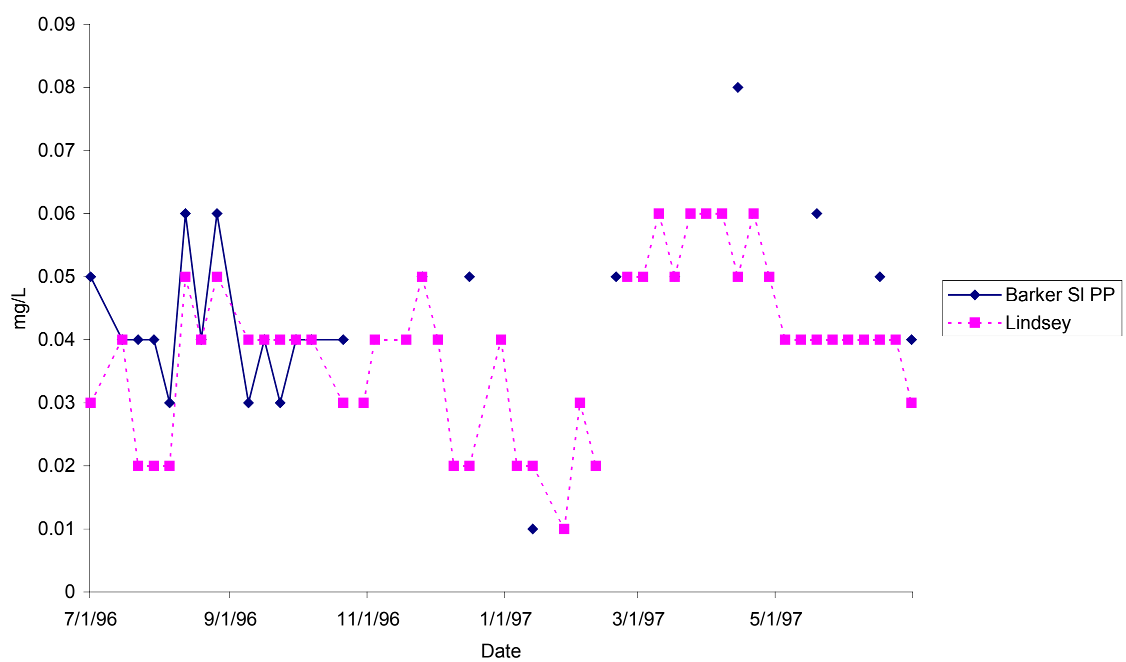


Table 3-9 Summary of Title 22 Violations (primary and secondary) for Quarterly Samples of Barker Slough Pumping Plant Analyzed by NBR, 1996 to 1999

Parameter (mg/L)	Mean	Median	Low	High	Percentile 10-90%	Detection Limit	# of Detects/ Samples
Total Aluminum	4.41	3.12	0.979	11.4	1.63 - 9.90	0.05	16/16
Total Iron	3.04	2.555	0.771	7.68	0.94 - 5.8	0.1	16/16
Total Managanese	0.09	0.082	0.046	0.271	0.06 - 0.11	0.03	15/16

3.4.2 WATER SUPPLY SYSTEMS

Treatment difficulties using NBA source water generally occur with winter storm events and heavy watershed runoff. Contractors consistently list high TOCs, turbidities, and loss of alkalinity as their major challenges in treating NBA water. In order not to exceed finished water turbidity and TOC standards, contractors have been forced to shut down plants that are unable to blend or switch to an alternate water source. Another challenging problem with storm events is the sudden, rapid changes in turbidity and TOC, which can force plants to shut down until enough jar tests can be performed to determine proper chemical dosages. The instability of NBA water quality requires frequent adjustments to chemicals and treatment schemes and requires continuous laboratory analytical testing. Rapidly changing turbidities also create problems in optimizing turbidity for pathogen control. When turbidities are fairly stable, contractors are able to meet the 2-log removal of *Cryptosporidium* at a filter effluent turbidity of 0.3 nephelometric turbidity unit (NTU). When turbidities change rapidly, the inability to calculate chemical dosages may compromise pathogen removal (Fleege pers. comm. 2000a).

Travis AFB WTP and the NBR WTP are the 1st to receive NBA water from the pumping plant. The cities of Benicia, Napa, and Vallejo are farther downstream and may benefit from potential settling out of contaminants due to distance and the presence of the Cordelia Forebay and Surge Tank. In the case of Vallejo, NBA water is conveyed through city-owned pipes from the Cordelia Forebay to Cordelia and Summit Reservoir, where more settling is possible. Because Vallejo blends its water (Table 3-1), it does not encounter the same problems with NBA water as some of the other contractors and was not included in this discussion.

3.4.2.1 Title 22 Constituents

As part of a cooperative agreement approved by the California Department of Health Services (DHS), NBR WTP staff conduct quarterly sampling for most Title 22 constituents (see Chapter 2) on NBA raw water for all NBA contractors. Exceptions include radionuclides, nonvolatile synthetic organic chemicals (SOCs), and asbestos. Radionuclide samples are collected at NBR WTP quarterly every 3 years. SOCs are sampled twice a year, once in the dry season and once in the wet season. Asbestos is sampled and analyzed once every 9 years. Organic and radionuclides data are used for compliance by all NBA contractors. NBA contractors sample and analyze their own treated water for all inorganic Title 22 constituents and may conduct their own in-house analyses on specific Title 22 compounds. NBA contractors use NBR WTP's raw water analyses to determine compliance for organics and radionuclides and their own treated water analyses to determine compliance for the remaining Title 22 compounds. The 1 exception is Napa at Jameson Canyon, which also uses NBR WTP's analyses of raw NBA water for inorganic compliance. Raw water analyzed by NBR WTP staff is collected at the Barker Slough Pumping Plant.

With the exception of Napa, there have been no Title 22 violations for any of the NBA contractors. Napa uses raw water to compare metal concentrations to the MCL. Aluminum has consistently exceeded the primary MCL of 1 mg/L. Following treatment, Napa's aluminum concentrations have never violated the MCL. Iron and manganese also routinely violate secondary MCLs. Again, after the water is treated, there have been no violations for either of these metals. Title 22 organic compounds are monitored quarterly by NBR WTP staff. From 1996 through 1999, no organic Title 22 compounds were detected (DeAlbidress pers. comm. 2000). Samples collected by O&M have only detected Dacthal (DCPA) once at 0.05 µg/L (DWR 1999, 2000a).

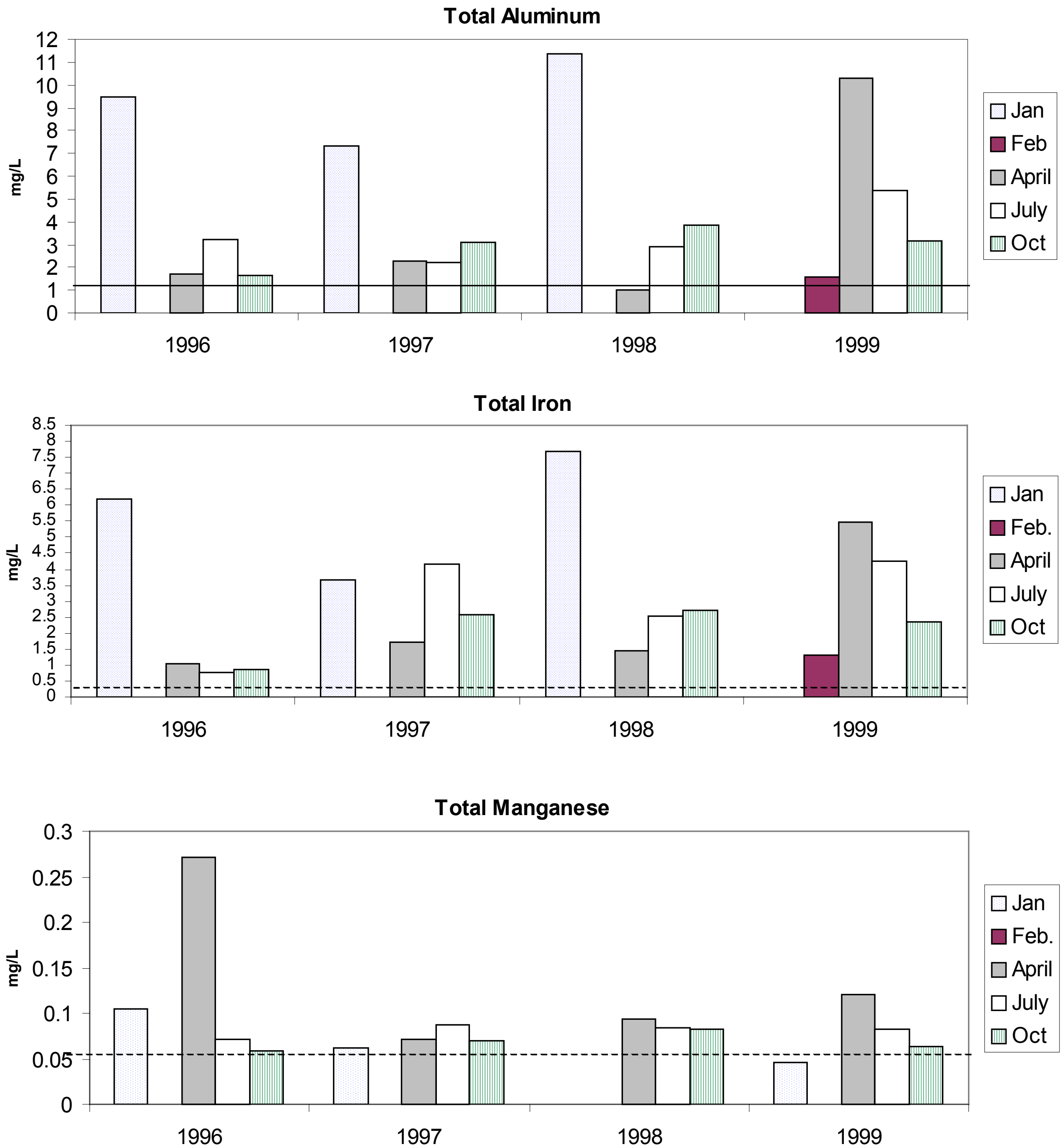
Table 3-9 and Figure 3-6 summarize NBR WTP's quarterly Title 22 analyses of aluminum, iron, and manganese. Iron or manganese showed no seasonal pattern. DWR data were not used to examine patterns because the majority of samples analyzed were for dissolved aluminum and more than 80% were below the detection level. Only 1 of the 16 samples collected in spring 1998 was below the primary MCL. Highest concentrations were generally detected in winter. With no other data, causes for the elevated aluminum concentrations are speculative. Aluminum phosphide is used for rodent control, but it is applied inside the rodent hole and should have minimal off-site movement (Vale pers. comm. 2000a). Aluminum concentrations may be highest in the winter due to the increased solubility of Al in lower pH rainwater. Also, increased particulates may result in the adsorption of Al resulting in elevated metal concentrations.

3.4.3 Key Constituents of Concern to NBA Contractors

3.4.3.1 Total Organic Carbon (TOC) and Alkalinity

Organic carbon levels are strongly influenced by the wet season. TOC influent data were pooled by month from 1996 through 1999 for several major NBA contractors and the Barker Slough Pumping Plant (Figure 3-7). Because data collected by utilities and DWR vary by sample date, time, and frequency, the pooled monthly averages cannot be compared directly. However, the data verify that for each utility, highest TOC concentrations primarily occur between December and April. Bracketing TOC concentrations between 2 and 4 mg/L—the lowest TOC range of source water requiring treatment under the Disinfectants and Disinfection Byproducts (D/DBPs) Rule (EPA 1998)—found that on average pumping plant and utility influent water always exceeded 2 mg/L TOC.

Figure 3-6 Quarterly Concentrations of Minor Elements in Raw Water Exceeding Title 22 Concentrations



(Primary MCL shown as solid horizontal line; secondary MCL shown as horizontal dashed line)

Figure 3-7 Average Monthly TOC Concentrations for Selected NBA Contractors, 1996 to 1999

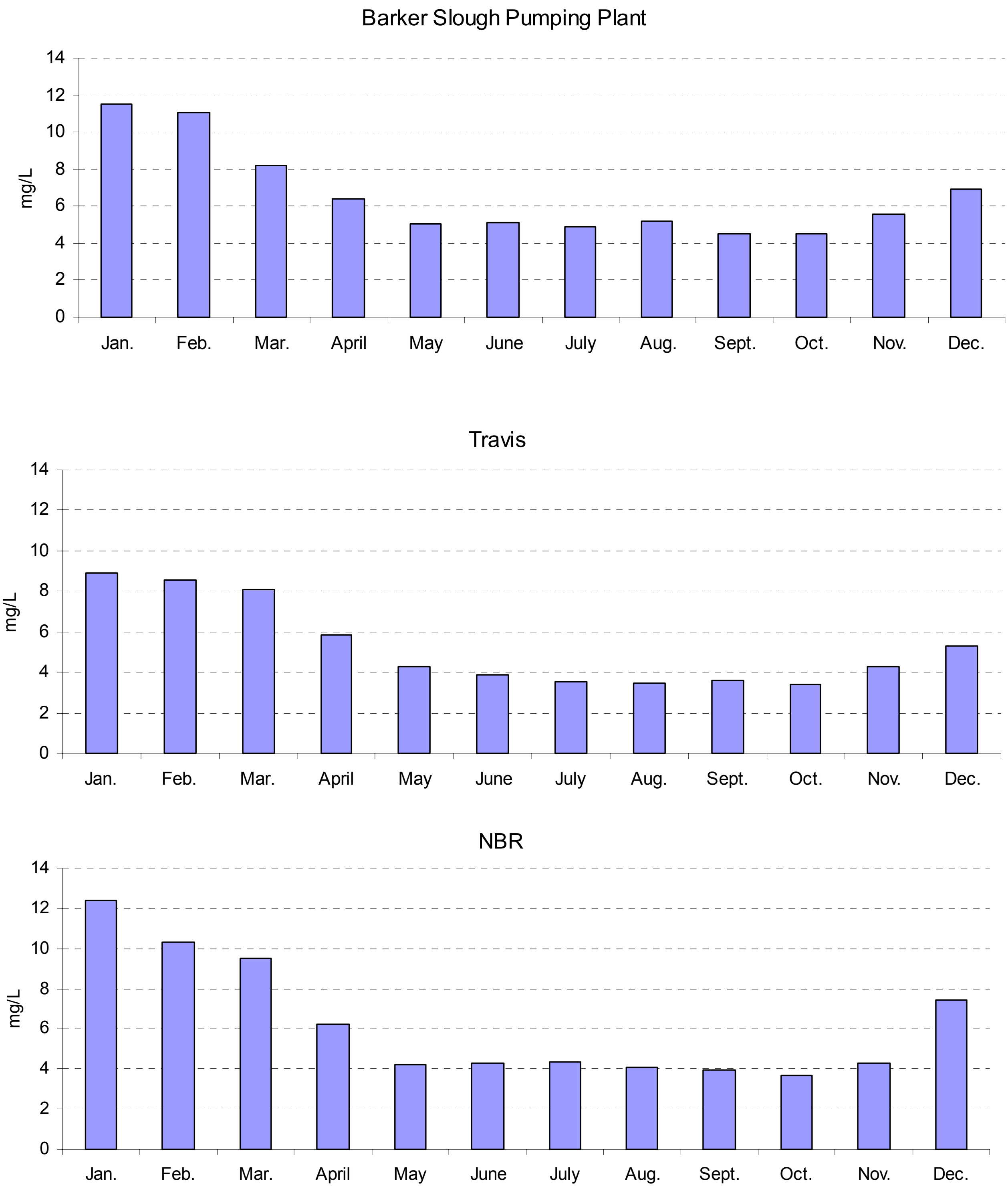
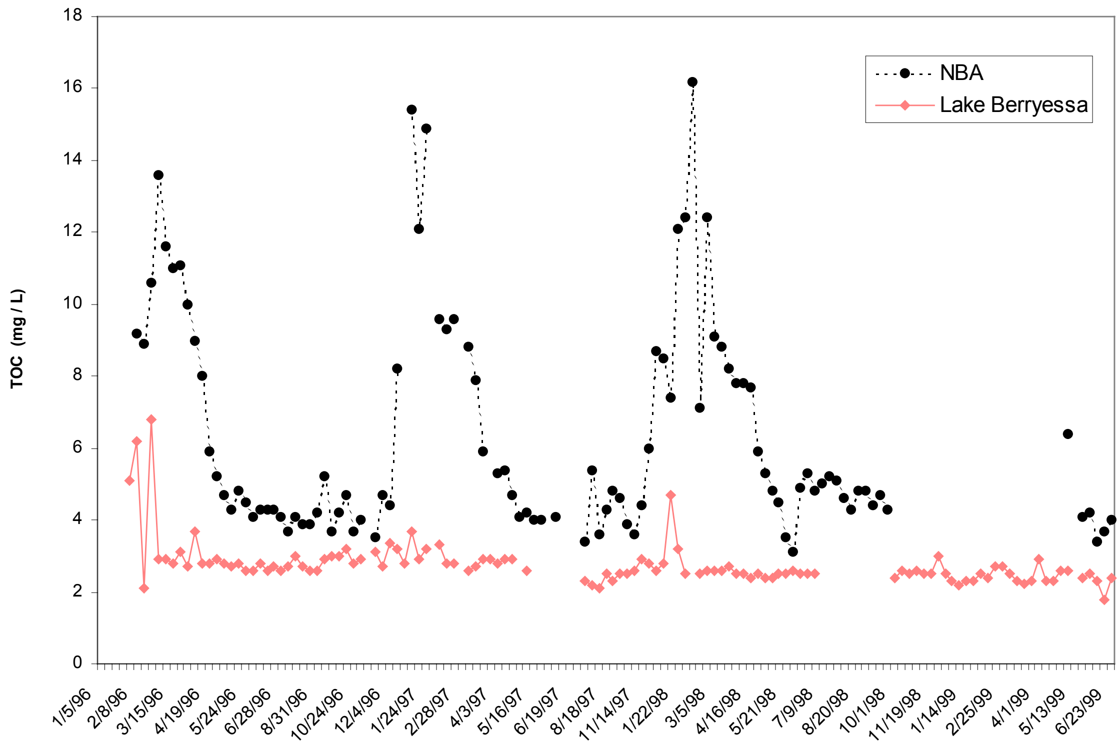
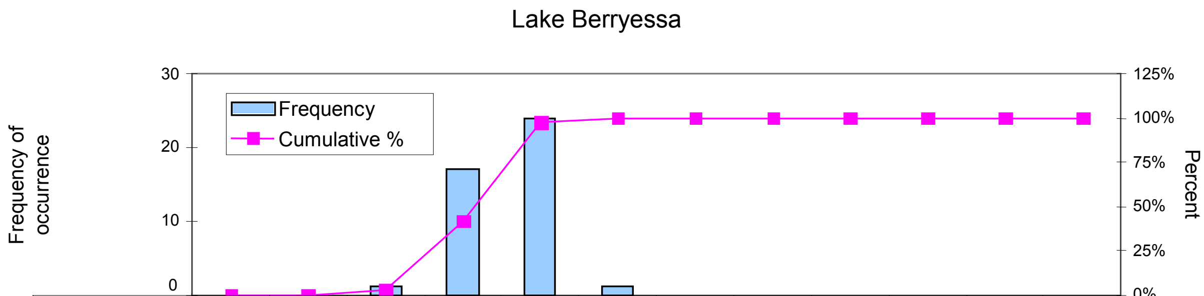


Figure 3-8 TOC Comparisons between North Bay Aqueduct Water at the North Bay Regional Water Treatment Plant and Lake Berryessa, 1996 to 1999

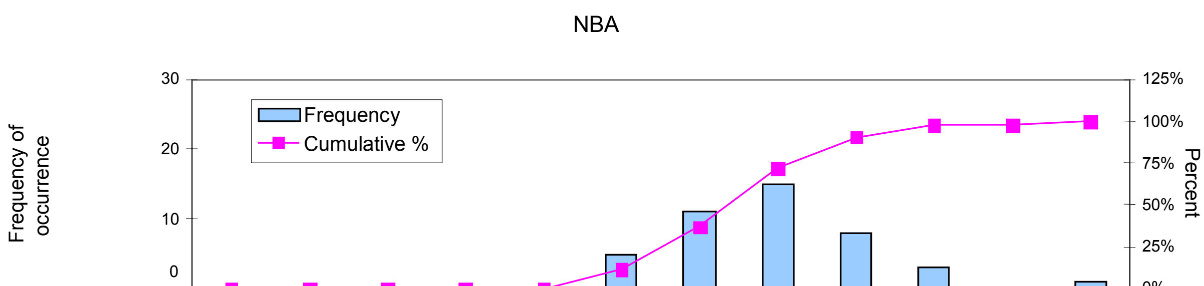


A comparison between NBA and Lake Berryessa TOC concentrations underscores the dramatic differences in water quality between the 2 sources (Figure 3-8). NBR WTP data were used to examine differences between NBA and Lake Berryessa water quality. Except when a source is not being used, NBR WTP staff maintains weekly TOC records for both NBA and Lake Berryessa water. Regardless of the season, NBA's TOC concentrations were consistently higher than those from Lake Berryessa water. In summer, Lake Berryessa TOC concentrations were less than 4 mg/L, whereas more than half of the NBA samples collected on the same date as those taken from Lake Berryessa were over 4 mg/L (Figure 3-9). Additionally, winter peaks in NBA TOC concentrations remained elevated over a longer period of time relative to Lake Berryessa water and were at higher concentrations than at the lake. For example, from November to April, more than 90% of influent Lake Berryessa TOC concentrations were less than 4 mg/L; for NBA waters, more than 90% were greater than 4 mg/L (Figure 3-10). Average weekly data do not show the rapid, unexpected peaks of TOC experienced during winter storms, but Figure 3-8 does illustrate the twofold jumps in concentration that NBA water can experience during the winter

Figure 3-9 Cumulative Probability Distribution of Summer TOC Values at Lake Berryessa and North Bay Aqueduct from NBR Data

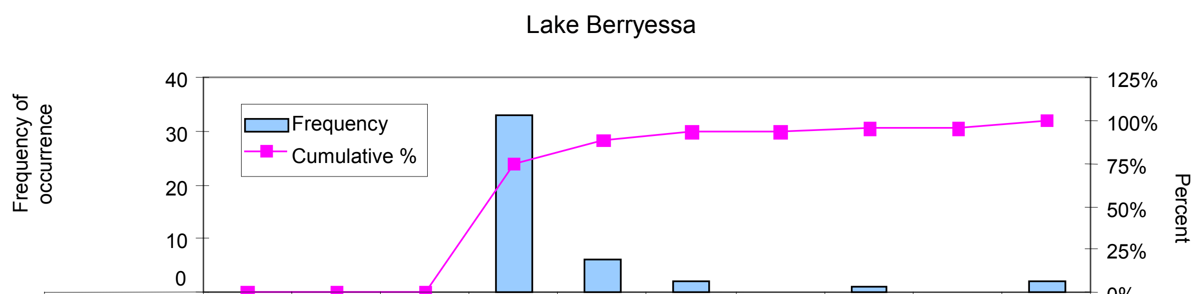


TOC (mg/L)	0	1	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5
Frequency	0	0	1	17	24	1	0	0	0	0	0	0
Cumulative %	0%	0%	2%	42%	98%	100%	100%	100%	100%	100%	100%	100%

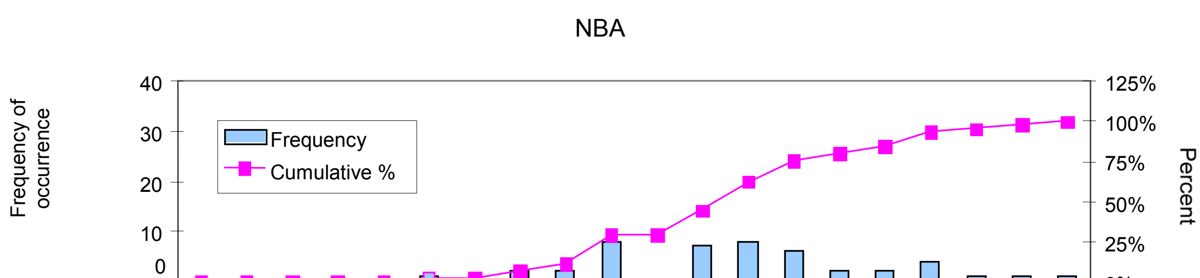


TOC (mg/L)	0	1	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5
Frequency	0	0	0	0	0	5	11	15	8	3	0	1
Cumulative %	0%	0%	0%	0%	0%	12%	37%	72%	91%	98%	98%	100%

Figure 3-10 Cumulative Probability Distribution of Winter TOC Values at Lake Berryessa and North Bay Aqueduct from NBR Data

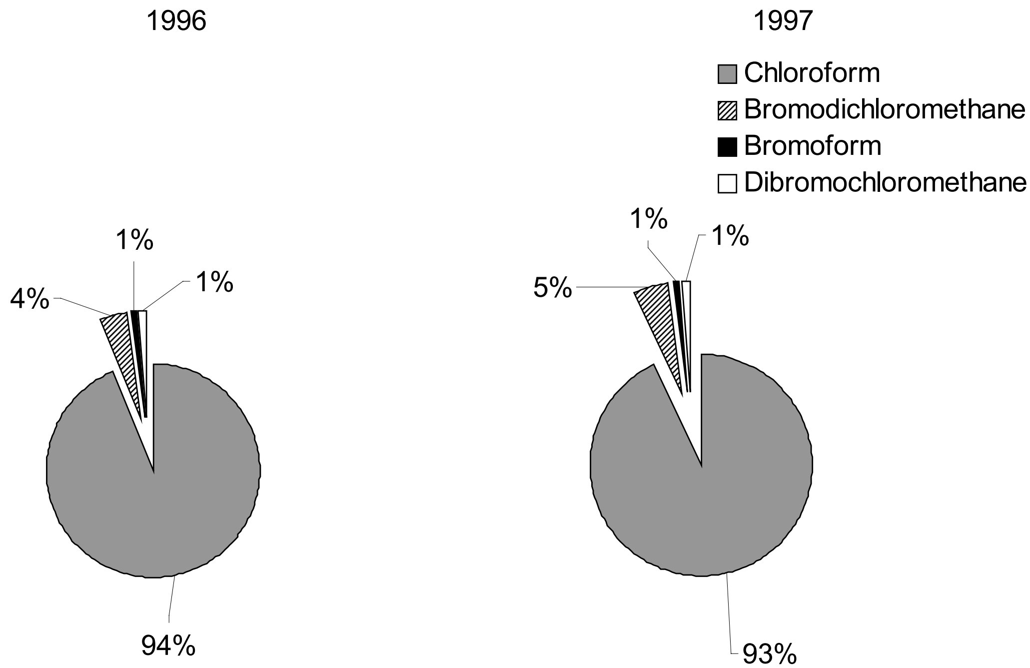


TOC (mg/L)	0	1	2	3	3.5	4	4.5	5	6	6.8
Frequency	0	0	0	33	6	2	0	1	0	2
Cumulative %	0%	0%	0%	75%	89%	93%	93%	95%	95%	100%



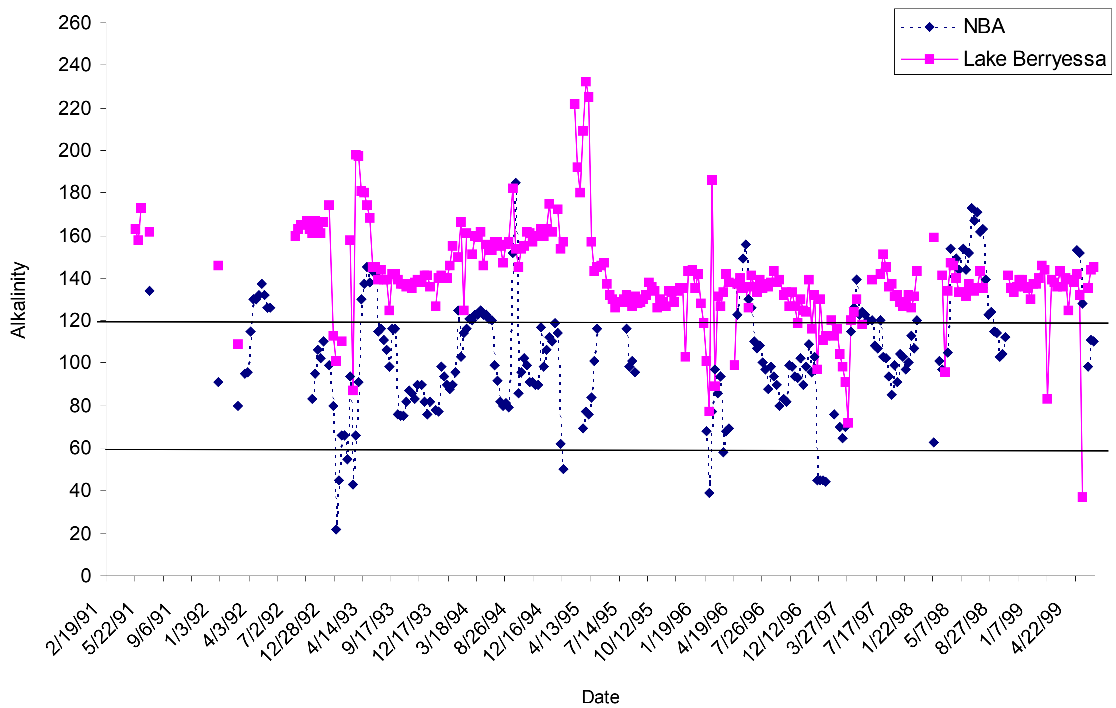
TOC (mg/L)	0	1	2	2.5	3	3.5	4	4.5	5	6	7	8	9	10	11	12	13	14	15	15.4
Frequency	0	0	0	0	0	1	0	2	2	8	0	7	8	6	2	2	4	1	1	1
Cumulative %	0%	0%	0%	0%	0%	2%	2%	7%	11%	29%	29%	44%	62%	76%	80%	84%	93%	96%	98%	100%

Figure 3-11 Relative Proportion of Individual Trihalomethanes Composing TTHMFP at the Barker Slough Pumping Plant



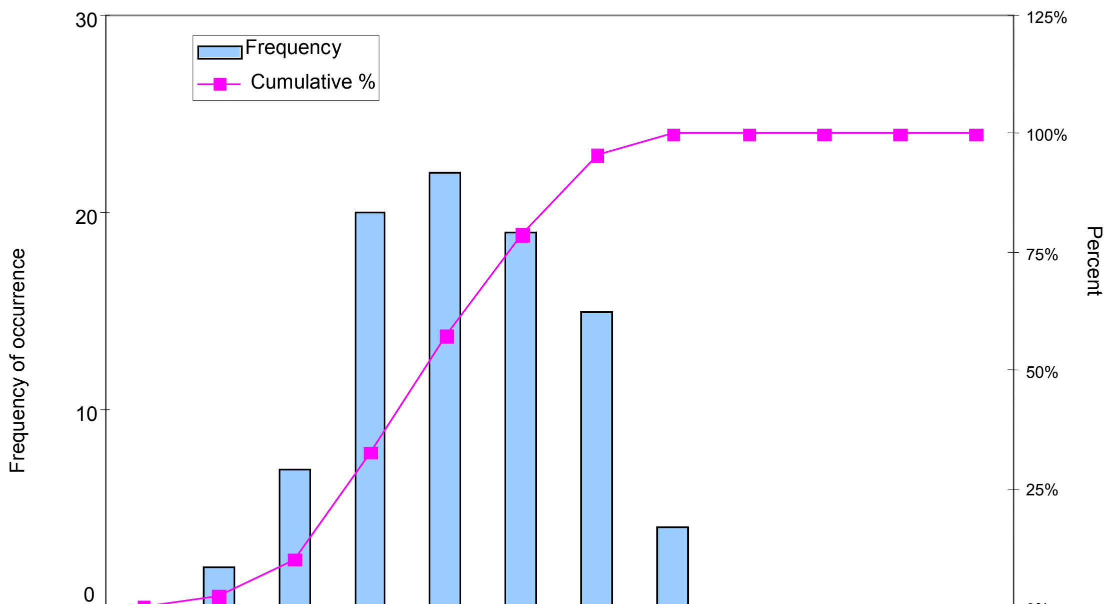
Trihalomethane precursors include organic carbon and bromide. Monthly samples show distinct seasonal patterns for each constituent. Peak concentrations of TOC are consistently observed in the winter. Concentrations have ranged from 1.0 to 38 mg/L, with an average of 7.2 mg/L (Table 3-5). Comparisons between median TOC concentration and its percentile ranges illustrate the skew of the data toward higher concentrations. When organic carbon from the pumping plant is subjected to chlorine oxidation, the majority of trihalomethane production is in the form of chloroform. In 1996 and 1997, more than 90% of the total trihalomethane formation potential was chloroform, followed by 4% to 5% bromodichloromethane with the remainder composed of dibromochloromethane and bromoform (Figure 3-11) (DWR 1999). These results suggest that from year to year the composition of the watershed's organic carbon may be relatively constant.

Figure 3-12 Comparison of Weekly Alkalinities between NBA and Lake Berryessa Water, 1991-1999 (NBR Raw Water Plant Influent)



Regardless of season, alkalinity in the NBA was lower than alkalinity in Lake Berryessa (Figure 3-12). Using NBR WTP data, the majority of NBA alkalinity values collected from 1991 through 1999 ranged between 60 and 120 mg/L, whereas the majority of Lake Berryessa water ranged between 120 and 180 mg/L. Based on TOC removal requirements under the D/DBP Rule, source water alkalinities between 0 and 60 mg/L will require the highest percentages of TOC removal (EPA 1998). Similarly, at TOCs greater than 8 mg/L, a level not uncommon to some NBA utilities, alkalinities between 60 and 120 mg/L also will require substantial percentage removals. According to NBR WTP data, the alkalinity concentrations of approximately 80% of the NBA water sampled between November and April were less than 120 mg/L (Figure 3-13). In the same time period, more than 50% of measured TOC concentrations were greater than 8 mg/L (Figure 3-10). This situation will make it difficult for WTPs that rely solely on NBA water. Elevated winter TOC levels create the potential for higher trihalomethane disinfection byproducts (DBPs). Low alkalinities make it difficult to remove enough TOC to meet MCLs of Stage 1 D/DBPs Rule. All NBA contractors are currently meeting these levels through a combination of strategies including increased coagulant usage, and blending or switching to another source. WTPs that cannot blend or switch to an alternate winter source are concerned that they will be unable to meet the Stage 2 D/DBP Rule (for example, Benicia, Napa, Travis). In the case of Stage 1 D/DBP Rule, Travis will need to practice enhanced coagulation. In some cases, these plants may not be able to meet Stage 2 D/DBP Rule and, therefore, total trihalomethane formation potential (TTHMFP)/haloacetic acids (five) (HAA5) limits.

Figure 3-13 Cumulative Probability Distribution of Winter Alkalinity – NBA Influent into NBR WTP



Alk. mg/L (as $CaCO_3$)	20	40	60	80	100	120	140	160	180	200	220	232
Frequency	0	2	7	20	22	19	15	4	0	0	0	0
Cumulative %	0%	2%	10%	33%	57%	79%	96%	100%	100%	100%	100%	100%

The low alkalinities associated with stormwater make it difficult for WTPs to reduce TOC/turbidity using alum as their primary coagulant. Some plants switch to more expensive or less effective coagulants; others add chemicals for alkalinity substitution so that their coagulants will work. Because of the high turbidities and TOC associated with NBA water, the water requires more alum, caustic, and ozone or other oxidant. The addition of more chemicals creates more sludge volume. NBR WTP staff estimates that about 935 pounds per day of extra sludge are generated at their plant when using NBA water in winter. Additional backwashing is required to handle the increased turbidity loading of the NBA. All of these factors lead to increased costs for treating NBA water. NBR WTP staff estimate that the cost of treating NBA water is nearly $200 per million gallons, approximately more than 2 to 4 times than for Lake Berryessa water.

3.4.3.2 Turbidity

High turbidities, including sudden unexpected peaks, generally occur in winter. At Barker Slough Pumping Plant, average daily on-line turbidities can change by more than a factor of 4 within 24 hours (Figure 3-14). All treatment plants that rely solely on NBA water experience the sudden changes in turbidity. Monthly turbidity ranges at the plants reflect the large turbidity changes (Table 3-10), but monthly averages and ranges do not show the rapid changes in NBA source water turbidity. For example, in January 1997 at the NBR WTP, influent NBA turbidities rose from 60 to 400 NTUs in fewer than 8 hours (Fleege pers. comm. 2000a).

Table 3-10 Average Monthly Winter Turbidity Levels for Selected Utilities, 1996 to 1999 (Ranges Shown in Parentheses)

Utility	Nov	Dec	Jan	Feb	March	April
Benicia[ab]	40 (18-298)	82 (20-274)	106 (18-280)	149 (99-228)	51 (14-181)	22 (12-41)
NBR WTP	52 (21.5-317.8)	80.8 (19.6-260)	144.5 (102-206)	160.1 (87.9-236)	65.9 (45-168)	34.5 (20.8-58.9)
Napa[b]	44 (21-428)	84.7 (21-344)	62.8 (20.3-105.2)	108.3 (27.1-189.5)	77.2 (52.3-130)	27.1 (19.2-32.2)
Travis	34 (18-321)	54.4 (15-236)	73.1 (14-273)	95 (15-221)	64.8 (30-181)	30.6 (13-59)

[a] No electronic data available for 1996.
[b] Averages calculated from maximum daily turbidities.

Figure 3-14 Average Daily Turbidity at the Barker Slough Pumping Plant, 1996 to 1999

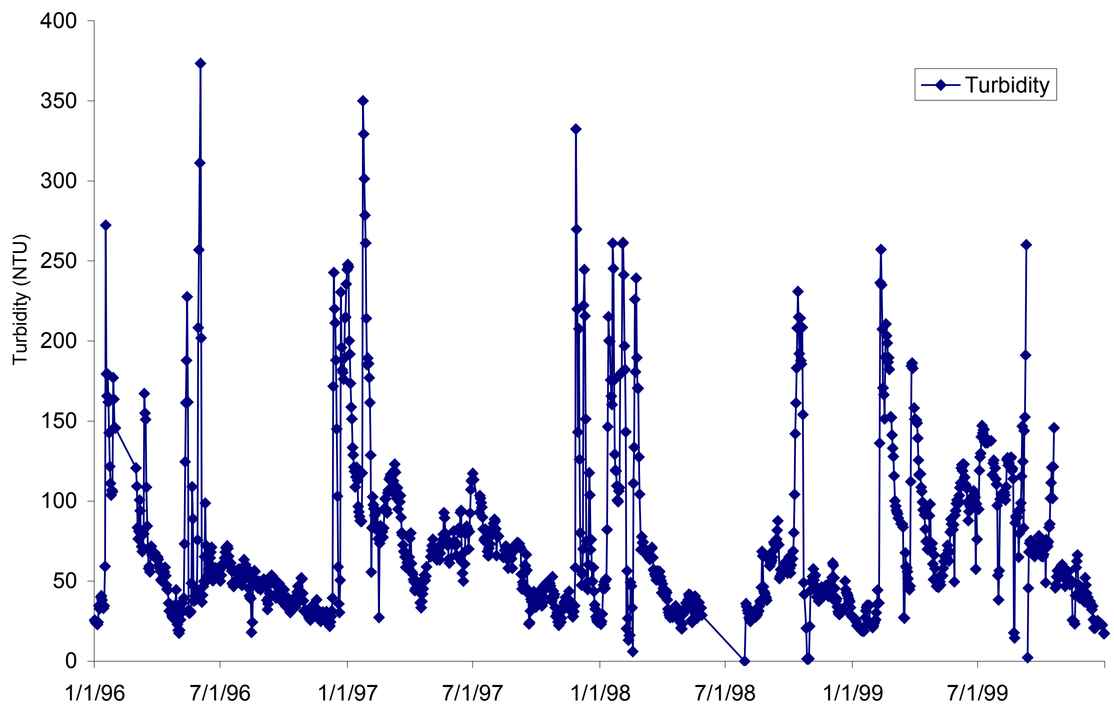
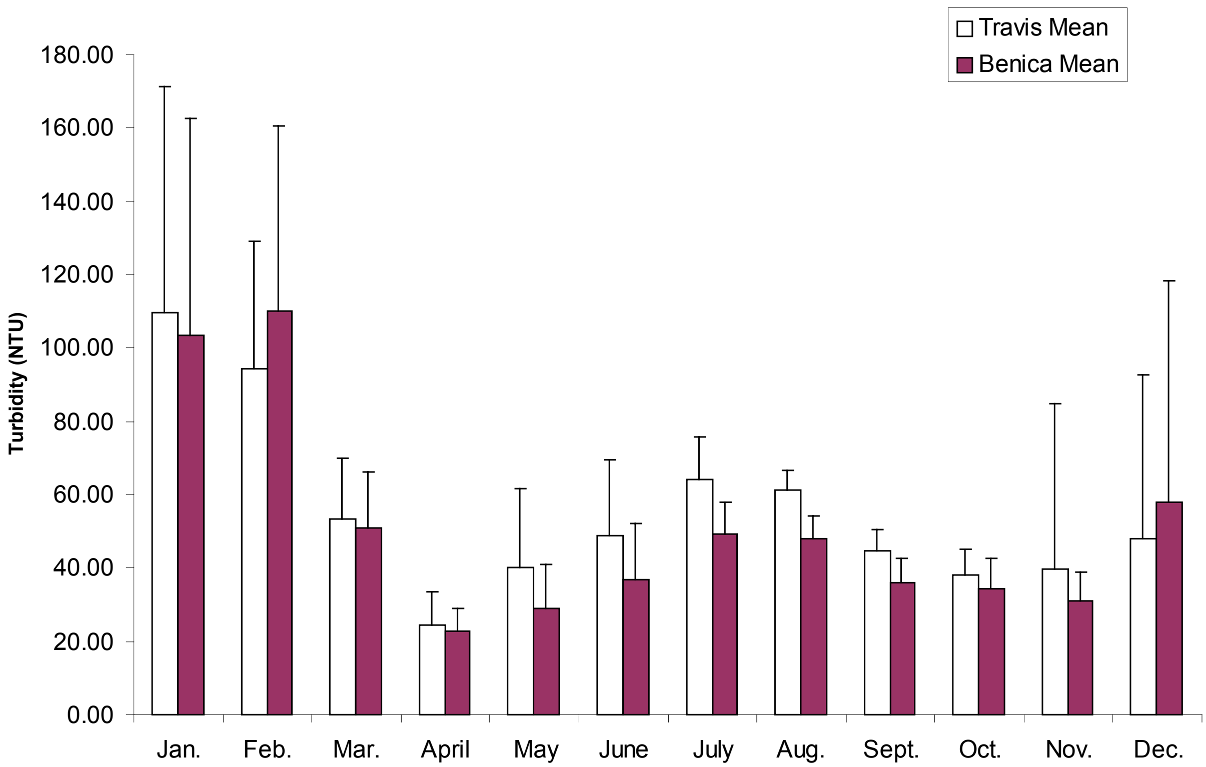


Figure 3-15 Comparison of Average Monthly Turbidities (+1sd) between Travis AFB and Benicia Water Treatment Plants, 1997 to 1998



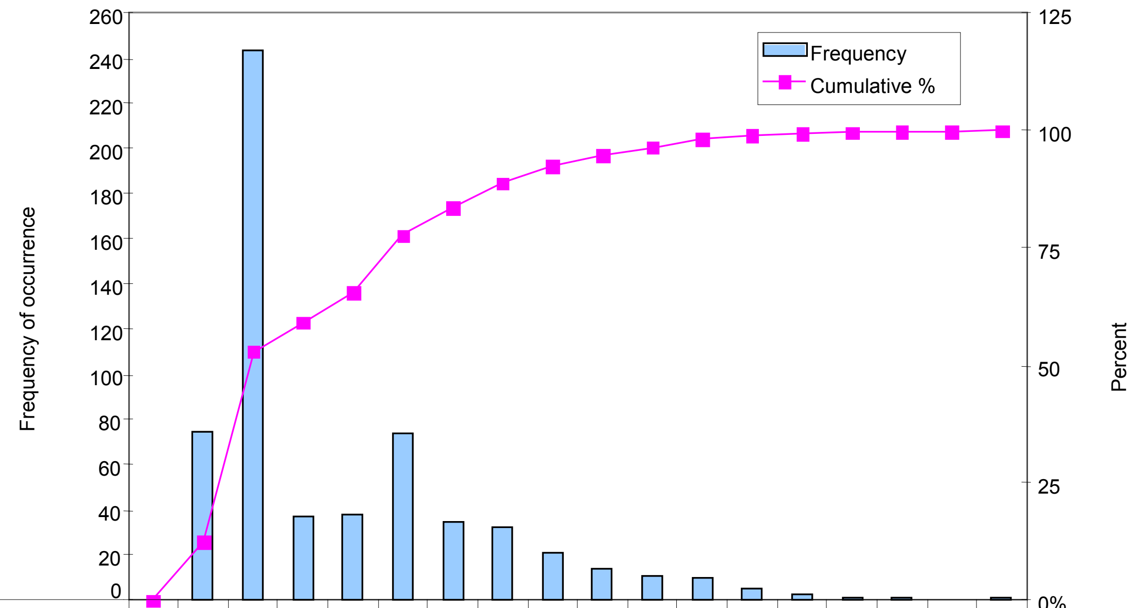
Turbidity comparisons between 1 of the WTPs closest to the Barker Slough Pumping Plant and the WTP farthest from the pumping plant suggested that particles responsible for plant turbidity do not settle out with distance. The influent line into Travis AFB WTP is approximately 10 miles from the pumping plant, whereas the influent line into the City of Benicia's WTP is approximately 34 miles away. In 1997 and 1998, more than 90% of the water used by both plants came from the NBA. Not only were turbidity patterns identical between the 2 plants (Figure 3-15), turbidity differences between the 2 plants never varied by more than 15 NTUs. While only 2 years of data were compared, the nearly identical turbidity readings from plants separated by more than 20 miles of pipeline suggested that the particles associated with turbidity never settled out of the pipeline. The large standard deviations associated with winter turbidities also shows the wide range of turbidities experienced by the 2 plants during winter months

Daily average turbidities for each month from 1996 to 1999 also show 2 seasonal turbidity peaks (Figure 3-16). In this figure, data between the 5 plants are not directly comparable. In some cases, utilities either blended or stopped using NBA water. In other cases, the plant shut down, electronic data were not available, or daily peak turbidity values were reported. However, given these caveats, all plants showed the same turbidity patterns. During late spring/early summer, turbidities increased steadily until July. Following July, turbidities decreased steadily until large jumps were observed in winter rainy season. This steady increase in turbidity was not as pronounced at the pumping plant, but average turbidities did increase by almost 40 NTUs between April and June. Increases in summer turbidity could be the result of irrigation return water or algal blooms.

Unlike turbidity, TOC concentrations did not steadily increase in summer. This may be due to the lower sampling frequency associated with TOC measurements. Plants normally reported a weekly TOC value, but turbidity values were based on daily averages calculated from turbidity measurements reported every 2 to 4 hours.

Figure 3-16 Average Monthly Turbidity for Selected NBA Contractors

Figure 3-17 Cumulative Probability Distribution of Average Winter Daily Turbidities at the Travis AFB WTP, 1996 to 1999



Turbidity (NTU)	10	20	40	50	60	80	100	120	140	160	180	200	220	240	260	280	300	321
Frequency	0	75	244	37	38	74	35	32	21	14	11	10	5	3	1	1	0	1
Cumulative %	0%	12%	53%	59%	65%	78%	84%	89%	92%	95%	97%	98%	99%	100%	100%	100%	100%	100%

Contractors for NBA water would prefer to treat water with daily average turbidities of not more than 50 NTUs with spikes not greater than 200 NTUs (Fleege 2000). At Travis AFB WTP, which relies solely on NBA water, approximately 60% of the daily winter turbidity values averaged 50 NTUs or less (Figure 3-17). Not accounting for sudden spikes in turbidity, this still leaves a significant percentage of days when daily turbidities averaged over 50 NTUs.

3.4.3.3 Pathogens

For a discussion of pathogen issues in the North Bay Aqueduct, refer to Chapter 12.

3.4.4 Results of Watershed Special Studies

Based on the difficulties in treating NBA water and the recommendations in DWR's *Sanitary Survey Update 1996*, MWQI began a series of special studies in 1996 to understand the relative contributions of different surface waters to water quality in the NBA. The summary of these studies focuses on several key constituents that affect WTP operation, namely turbidity and organic carbon.

3.4.4.1 1996/1997 Special Studies

The 1st year of watershed studies focused on inputs from all the major water sources to the Barker Slough Pumping Plant (DWR 1996). Samples were collected weekly from July 1996 to June 1997 from 4 sites (Figure 3-1):

- Lindsey Slough near the Sacramento River,
- Calhoun Cut (approximately a mile downstream of the plant),
- Barker Slough at Cook Lane, and
- Barker Slough Pumping Plant.

Results from this yearlong sampling confirmed that the majority of water quality problems at the pumping plant occurred during winter rainy season. For example, dissolved organic carbon (DOC) and turbidity increased at all sites in winter (Figures 3-18 and 3-19), while alkalinity values fell (Figure 3-20).

Figure 3-18 Dissolved Organic Carbon Results for NBA Watershed Study, 1 Jul 1996 to 30 Jun 1997

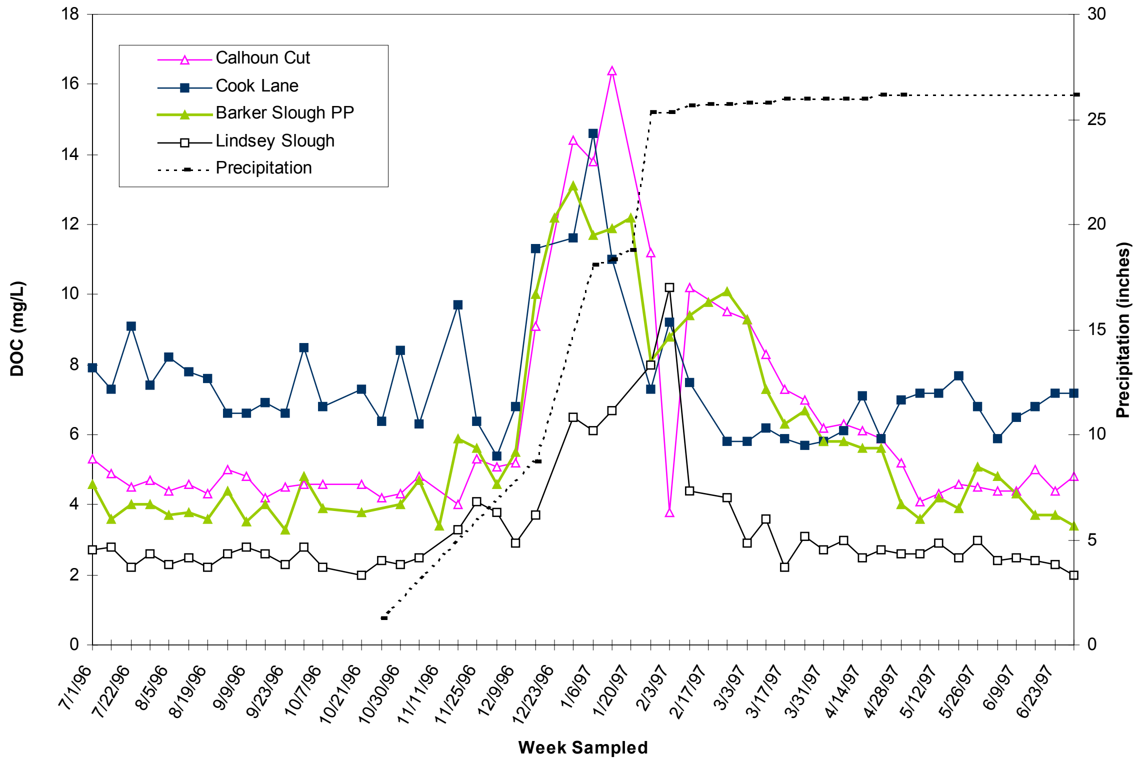


Figure 3-19 Turbidity Results for NBA Watershed Study Sampling Sites, 1 Jul 1996 to 30 Jun 1997

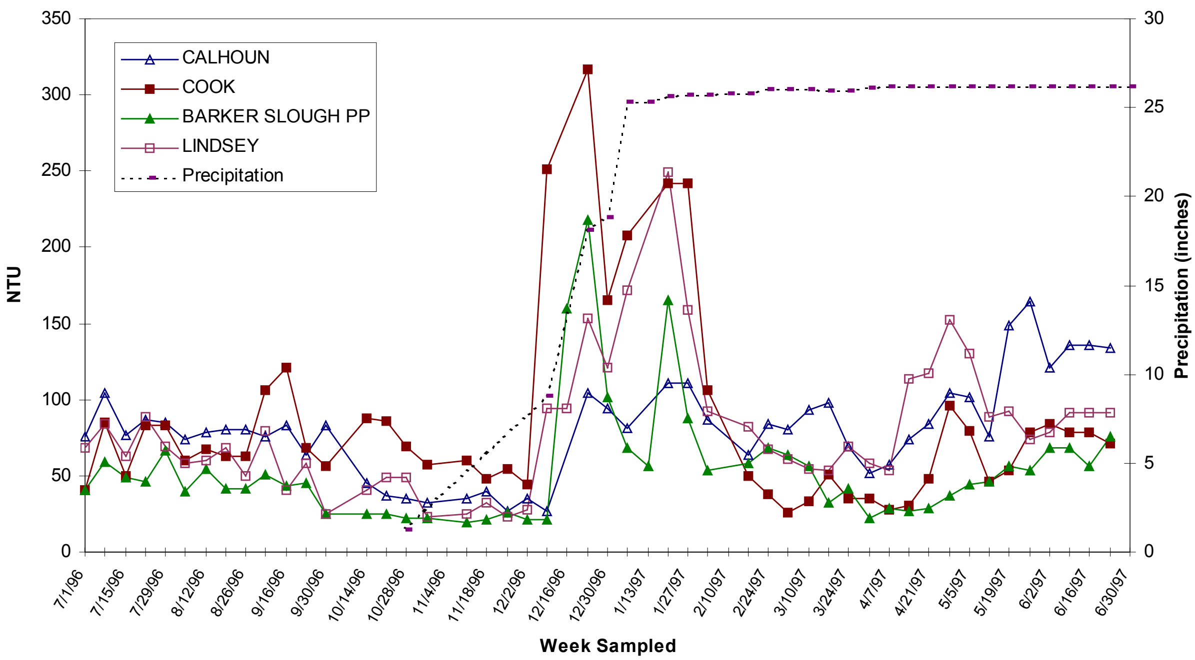
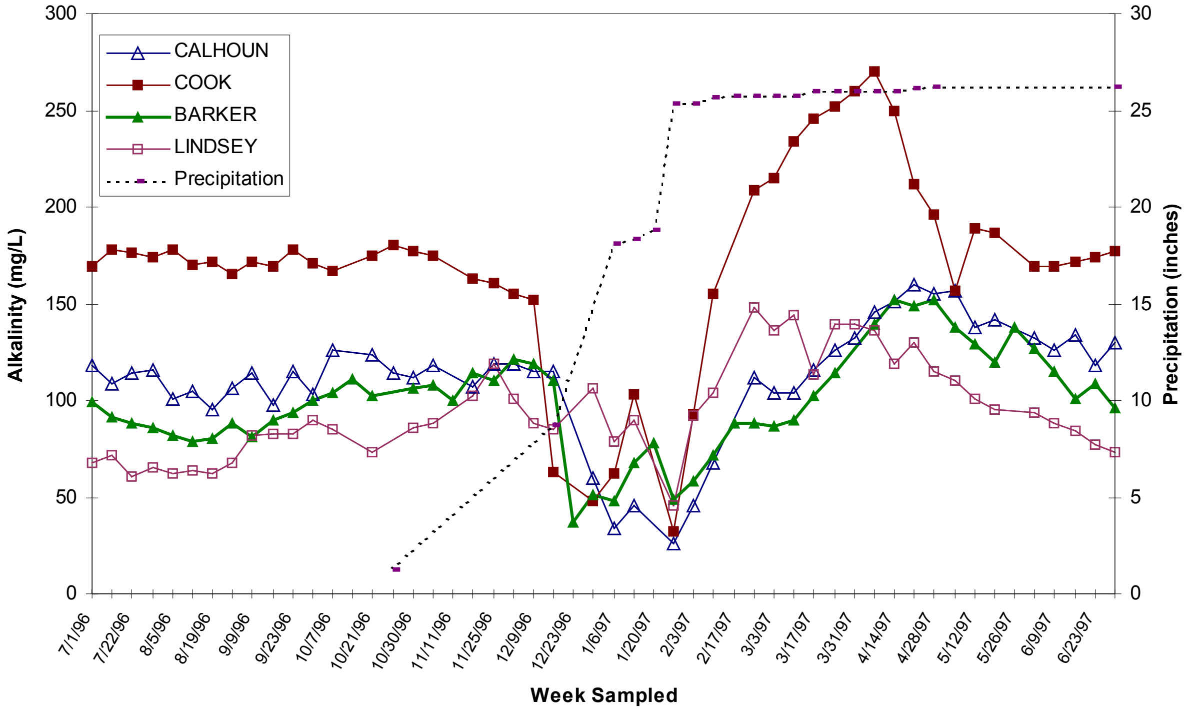


Figure 3-20 Alkalinity Values for NBA Watershed Study Sampling Sites, 1 Jul 1996 to 30 Jun 1997



The influence of upstream and downstream sites on organic carbon concentrations at the pumping plant appeared to be seasonal. In the winter, with respect to organic markers (DOC and THMFP), the Sacramento River did not appear to influence water quality at the pumping plant. For example, during the winter rainy season, DOC concentrations upstream of Lindsey Slough were twice as high as those detected at Lindsey Slough (Table 3-11). In summer, DOC concentrations at the pumping plant generally fell between those concentrations observed at Lindsey Slough and at Calhoun Cut (Figure 3-18). Unlike the other sites sampled, Cook Lane's average summer DOC concentrations remained elevated at winter levels, suggesting that upstream sites had little impact on summer pumping plant water quality. Experiments conducted in following years began examining the sources of contaminant loading from the upper reaches of the watershed. Since summer organic carbon and turbidity levels are manageable for the treatment plants, subsequent studies focused on watershed dynamics in the winter.

Table 3-11 Average Annual Summer and Winter DOC Concentrations near the Barker Slough Pumping Plant, Jul 1996 to Jun 1997 (mg/L ± sd)

Site	Yearly	Summer	Winter
Lindsey Slough	3.3 ± 1.7	2.5 ± 0.27	4.2 ± 0.44
Calhoun Cut	6.1 ± 2.9	4.6 ± 0.29	7.9 ± 0.74
Barker Sl PP	6.0 ± 2.8	4.0 ± 0.47	7.8 ± 0.55
Cook Lane	7.5 ± 1.8	7.3 ± 0.75	7.7 ± 0.53

Yearly average = Jul 1996 to Jun 1997
Summer average = May to Oct
Winter average = Nov to Apr

.

Table 3-12 Average Concentrations of Turbidity, TOC and DOC by Site and Rainfall Period for the 1997/1998 Winter Sampling Season (Ranges Given in Parentheses)

	Turbidity (NTUs)		TOC (mg/L)		DOC (mg/L)	
Sample Site	Baseline (pre-rainfall)	Wet	Baseline (pre-rainfall)	Wet	Baseline (pre-rainfall)	Wet
Lindsey Slough	32.5 (31-35)	68.8 (38-162)	3.0 (2.7-3.2)	5.5 (3.8-6.2)	2.2 (2-2.3)	5.0 (4-5.5)
Calhoun Cut	45.2 (37-54)	73.6 (43-112)	6.3 (6.2-6.3)	15.3 (11.3-20.7)	4.8 (4.4-5.2)	12.3 (10.3-15.9)
Barker Sl PP	46.7 (44-51)	176.2 (102-256)	6.1 (5.5-7)	14 (12 -20.3)	4.8 (3.4-6)	9.5*
Cook Lane	111.4 (95-128)	366.2 (304-469)	9.4 (8.8-10)	17.7 (13.9-20.5)	6.2 (6-6.4)	11.6 (9.9-12.8)
Dally Road	60 (50-70)	192.8 (49-436)	8.8 (4.8-12.8)	16.1 (11.2 -20)	7.7 (4-11.4)	12.4 (9.6-15)
Hay Road	32.7 (18-47)	354 (23-608)	9.4 (3.7-15.1)	13.4 (10.8-17.4)	9.1 (3.4-14.8)	9.8 (6.1-16.1)

Baseline = Sep 1997 to Nov 1997; Wet = Dec 1997 to Feb 1998
* Only 1 sample analyzed

3.4.4.2 1997/1998 Special Studies

Follow-up experiments confirmed that water quality from the Sacramento River via Lindsey Slough did not impact the winter water quality at the Barker Slough Pumping Plant. In winter, turbidity, TOC, and DOC were generally higher at all sites above Lindsey Slough (Table 3-12). In addition, turbidity and TOC data showed that water quality did not improve upstream in the watershed. For example, some of the highest average turbidities were observed at sampling points farthest upstream.

During this 2nd year of study, when stream and weather conditions permitted, flow measurements were collected by DWR staff. The goal was to understand the loading contributions of different sites in the watershed Over the course of a single day, concentration and flow data were collected from the uppermost sampling site to the lower boundary of the watershed. Based on loading, the pounds of carbon entering the slough increased over 30-fold from the uppermost site sampled (Hay Road) to the Cook Lane site approximately a mile above the pumping plant (Table 3-13). This showed that there were many sources of organic carbon throughout the watershed with the largest carbon inputs occurring in the lower half of the watershed.

Table 3-13 Flow and TOC Loading in the Barker Slough Watershed from the Uppermost to Lowermost Site in the Watershed, 17 Dec 1997

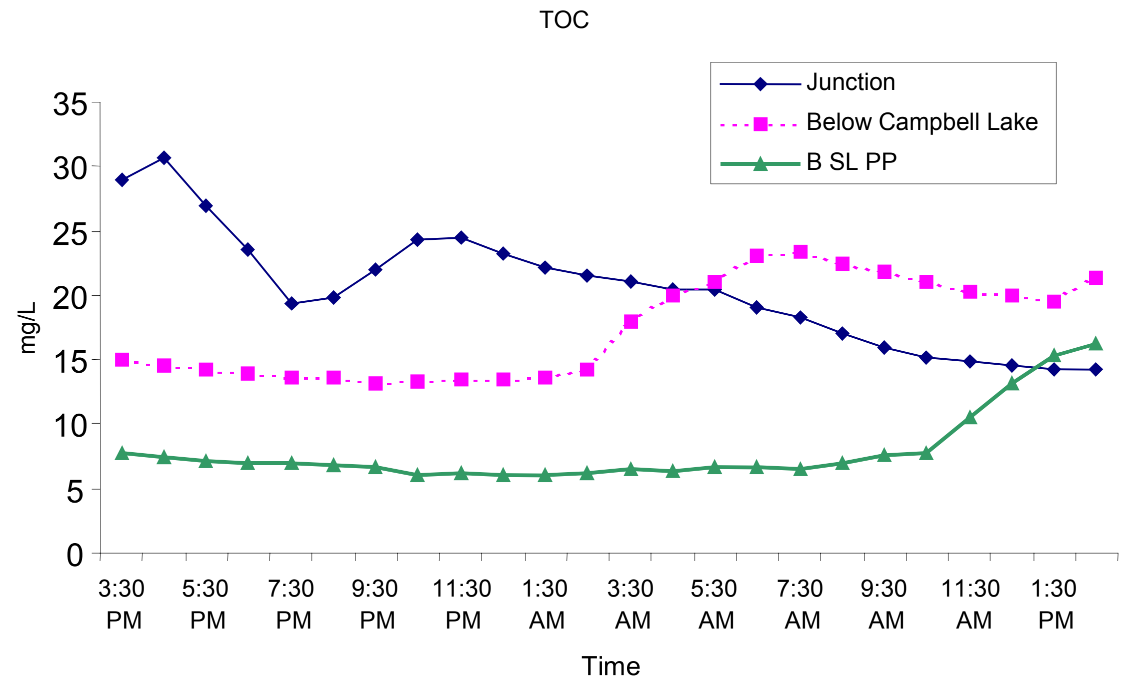
Site	cfs	TOC (mg/L)	Loading (lbs/day)
Hay Road	0.26	10.9	15.24
Dally Road	1.03	11.2	62.07
Cook Lane	5.26	19.3	546.23

3.4.4.3 1998/1999 Special Studies

In the 1998/1999 winter sampling season, DWR staff collaborated with a number of NBA contractors to examine the dynamics of turbidity and TOC during storm events in the upper watershed. Using loading, the objective was to determine the relative inputs of TOC, DOC, and turbidity from different land use areas in the watershed. Sampling points isolated key land uses in the watershed and/or inputs to the system from a particular area of interest. On-line flow, turbidity, and rain gauges and remotely triggered autosamplers were installed at the sites. In addition, weekly grab samples were collected at the pumping plant to validate patterns seen in previous studies and to examine patterns of water quality between storm events.

In the 1998/1999 winter sampling season, 2 dynamics were observed in the watershed. Autosampler results generally showed a strong spatial and temporal component associated with TOC and turbidity (Figure 3-21). Autosampler data suggested that the progression of peak concentrations of TOC and turbidity were related to a storm's intensity and/or the saturation level of soils. For example, in December, peaks of TOC and turbidity were observed during a small rainfall event at the uppermost site. Downstream, below Campbell Lake and at the pumping plant, no TOC or turbidity peak was observed. In February, during 1 of the largest storms of the season, the turbidity/TOC peak moved down the watershed and was recorded by the pumping plant's on-line turbidity meter, suggesting that the upstream watershed was influencing the pumping plant water quality.

Figure 3-21 Autosampler TOC and Turbidity Progression, Feb 1999



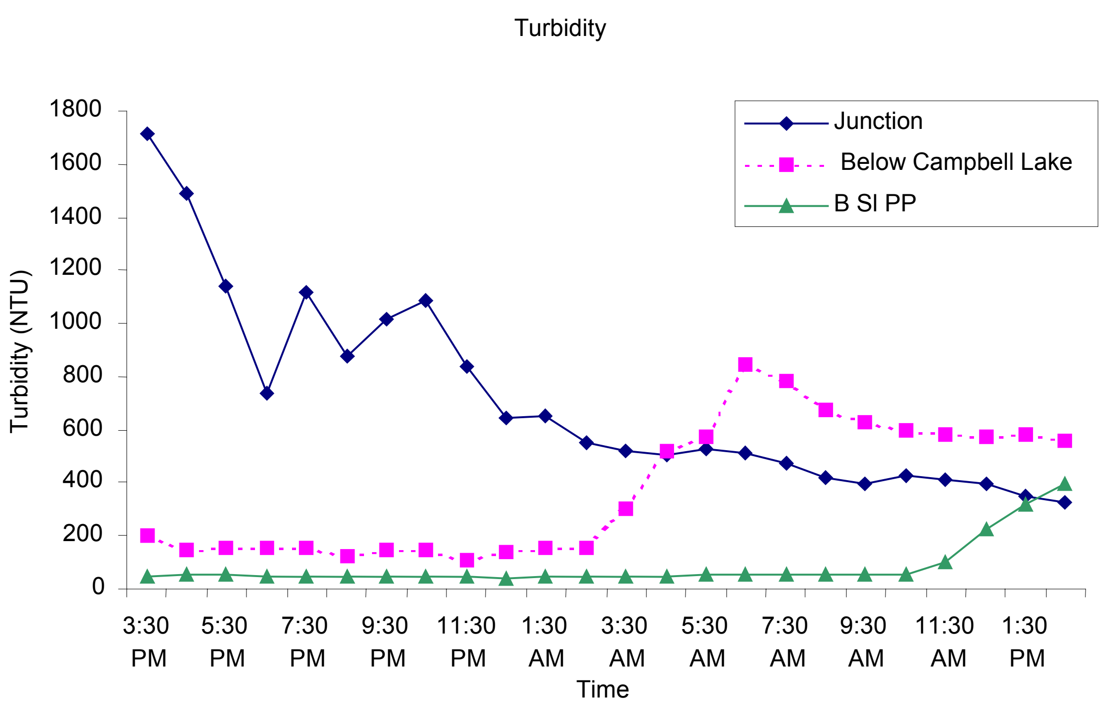
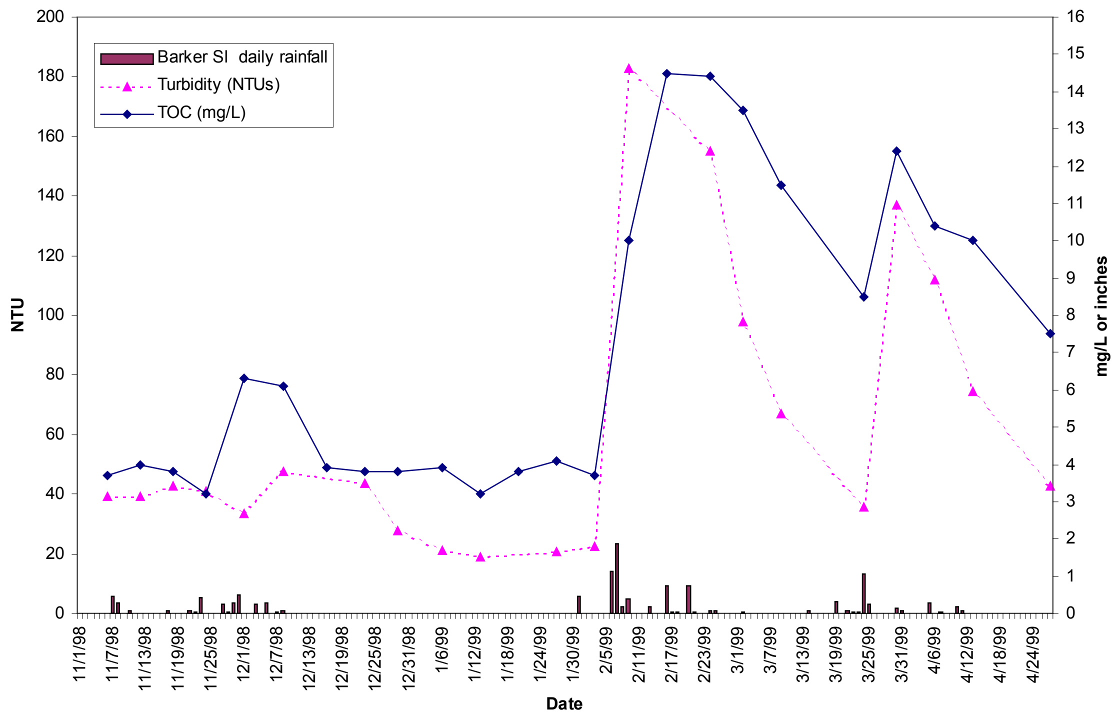


Figure 3-22 Weekly Turbidity and TOC at Barker Slough vs. Rainfall, Nov 1998 to Apr 1999



The weekly grab samples collected at the pumping plant highlighted a separate phenomenon that was not directly tied to a rainfall event. Grab samples collected weekly at the pumping plant showed that TOC and turbidity levels remained elevated at the pumping plant for a 3-month period, regardless of rainfall activity (Figure 3-22). For example, in the first 3 weeks of March, the pumping plant received less than 0.5 inches of rain, yet TOC concentrations averaged 11 mg/L. In comparison, the pumping plant in February received over 5 inches of rain with TOC concentrations averaging 9.3 mg/L.

Unfortunately, loading inputs relative to each of the sample sites could not be calculated over a whole sampling event. In all cases, due to inherent physical difficulties with the streambed's morphology, flow measurements were not calculated for water leaving Campbell Lake. In 1 case, TOC measurements were not collected because the storm damaged the sampling equipment.

A literature search of the soil characteristics in the watershed suggested that shallow groundwater and alkaline clay soils in the area could account for the high TOC and turbidity levels. Soil surveys conducted by the US Department of Agriculture showed that many of the watershed's soils contain high levels of sodium (Bates and others 1977). Soils high in sodium (sodic soils) may influence water quality in 2 ways: 1) Sodium ions are large monovalent ions that enhance clay swelling and dispersion, leading to higher turbidity. 2) Sodium tends to raise a soil's pH, increasing dispersion of organic carbon (US Salinity Laboratory Staff 1954, Sposito 1989, Shainberg 1990, Singer 1999, Goldberg and others 2000). The clay subsoils and the shallow groundwater level that create the area’s vernal pools may also be responsible for the widespread ponding and flooding observed in the watershed.

Special studies continued into the 1999/2000 sampling season. Results are not covered in-depth in this report. However, when loads could be calculated, those at the uppermost site (representing urban and some row cropping land use) were between 4.5 and 100 times lower than loads exiting Campbell Lake. Like the 1998/1999 sampling season, following the saturation of the watershed, TOC concentrations remained elevated in weekly pumping plant samples even in the absence of rainfall.

Loading calculations suggest that, in the absence of rainfall, excessive loading of these constituents into the forebay may be the cause of the pumping plant's elevated TOC and turbidity levels. Using the plant's average pumping rate and the pounds per day of carbon exiting Campbell Lake, sample collections in Table 3-14 show the pounds per day pumped by the pumping plant. For 3 weeks the carbon load exiting Campbell Lake was well above the load exported by the pumping plant. This indicates a possibility that during and after large storm events, large quantities of TOC and turbidity continue to feed the plant's forebay. As the 1996/1997 study showed, Lindsey Slough water has little influence on winter water quality. One hypothesis is that the lack of winter flushing between the pumping plant and Lindsey Slough occurs from the formation of a hydrologic plug from the Yolo Bypass. Additionally, points downstream of the forebay (for example, Calhoun Cut) may contribute to the reservoir of carbon at the forebay because their outflow would also be blocked. In the absence of rainfall, the pumping plant would continue to pump from this TOC reservoir until the high TOC/turbidity was exhausted and/or hydrologic conditions changed.

Table 3-14 Organic Carbon Load Exiting Campbell Lake vs. Organic Carbon Load Pumped at the Barker Slough Pumping Plant

	Camp Lk (lbs/day)	BSl (lbs/day)	Percent
Jan 26	1,727	5,162	33
Feb 2	131	1,860	7
Feb 9	223	1,149	19
Feb 16	4,064	1,397	290
Feb 23	9,104[a]	2,057	443
Mar 1	3,054	1,928	158
Mar 8	833	930	90
Mar 15	268	1,016	26
Mar 22	221	4,494	5
Mar 29	189	1,690	11

Shaded area: Load from Campbell Lake exceeded load pumped by the pumping plant
[a] Estimated load using flow from Junction. Slough overtopped its banks at Campbell Lake gaging station

3.5 SIGNIFICANCE OF POTENTIAL CONTAMINANT SOURCES

NBA water often exceeds primary MCLs for aluminum. Levels are generally highest in the winter and may be caused by the increased metal solubility in low pH waters, the increase in particulates associated with winter storms, or the potential lack of flushing of the forebay during the winter. Concentrations may reflect natural background levels in the watershed. With no other data, the cause for elevated aluminum concentrations is speculative. NBA water also often exceeds secondary MCLs for iron and manganese. This cause also is unknown, but as with aluminum, the elevated concentrations may be tied to the natural physical-chemical dynamics of the watershed itself.

The main water quality issues consistently challenging NBA contractors are the high levels and/or rapidly changing levels of organic carbon and turbidity. Of the PCSs examined—recreational use, septic systems, livestock grazing, pesticide/herbicide usage, underground storage tanks, and unauthorized activity—only recreational use and livestock grazing had the potential to have an impact on TOC and turbidity.

Of the 3 recreation sites, Argyll Park has the strongest impact on turbidity and TOC. The large dirt motocross area drains into a small pond near Campbell Lake. The pond is generally more turbid than the lake. It is not known how the pond is operated. However, the water released from this pond can join with Barker Slough downstream of the outlet from Campbell Lake. Campbell Lake, which is minimally used for recreation, plays a role in the high TOC and turbidity levels because of its location on Barker Slough. The lake could serve as a sink for larger particle sizes, but data suggest this shallow lake may serves more as a holding area for high turbidity water than as a settling basin for the finer silt that makes up a large component of the turbidity. Until a storm of sufficient intensity allows runoff to pass through Campbell Lake, impacts from the Barker Slough watershed may not be felt at the pumping plant.

Livestock grazing has the most obvious influence on organic carbon and turbidity in the watershed. Cattle more than sheep have the greatest potential to affect the watershed's water quality because of their greater numbers, their longer residence time in the watershed, and their habit of wading in the stream. Sheep generally do not wallow or stand in watercourses for any length of time.

Cattle standing in the slough also are a direct source of pathogens and organic carbon. Fecal material on land can be transported during storm events and serve as a potential source of carbon and/or pathogens. If calves are present in the watershed during winter, then the potential for Cryptosporidium and Giardia contamination increases because both organisms retain their infectivity under cool, damp conditions (Olson and others 1999) and because young animals shed more pathogens than adults.

The lack of proper fencing leaves much of the slough accessible to livestock. Areas around streams are highly disturbed and susceptible to erosion. In summer, the slough may be the only source of water for livestock; in winter, the paths leading into the slough are devoid of vegetation and more susceptible to erosion.

A 2nd source of erosion may be the Noonan Main Drain, as well as the majority of access roads that are unpaved. The drain is mostly unlined and in the past has been kept clear of vegetation. Present weed control practices are changing, and revegetation of the bank may lessen erosion. However, grasses cannot prevent bank scouring during high flows or prevent bank slumping. Where no vegetation is present along the banks of the drain, rivulets have been observed.

In addition to livestock disturbances, physical properties of the soil also may be a large contributor to the TOC and turbidity problems. It has been suggested that the high sodium content within the horizons exposed by channel incisions, etc. is the single most important factor in creating the type of persistent turbidity associated with runoff from the Barker Slough watershed (Hydro Science 2000). Based on limited data, Hydro Science concludes that the channel system, and not the contiguous disturbed areas, produces most of the sediment load. In addition to the physical-chemical properties of the soils, the hydrologic conditions that develop in the winter may prevent stormwater from the Barker Slough watershed and points downstream from moving away from the pumping plant. This appears to result in the pumping plant drawing from a "pool" of high TOC water until hydrologic conditions change.

3.6 WATERSHED MANAGEMENT PRACTICES

With the exception of the program at Jepson Prairie Preserve, range management practices of area landowners are unknown. Local meetings have been poorly attended, and landowners in the area may not trust inquiries from outside agencies. Campbell Lake, which is under the control of the owners of Argyll Park, is not managed to control outflow in the winter when most of the problems occur. The landowner noted that he dams the lake in summer to provide irrigation water and removes the boards in the winter to prevent flooding.

In late 1999, the SCWA was awarded a grant from the State Water Resources Control Board to conduct pilot BMPs in the watershed. There are obvious BMPs that can be put into place that promote good land stewardship, for example, fencing cows out of the slough and moving livestock water supplies away from the slough. In July 2000, the SCWA hired Hydro Science to recommend and evaluate the potential effectiveness of traditional BMPs in addressing contractors' concerns. Hydro Science proposed and ranked 21 different BMPs and concluded that there were more opportunities available to reduce turbidity than organic carbon (Table 3-15). At the time of this report, the firm's recommendations had just been released. Contractors had not reviewed and discussed the results. No grant-related activities are anticipated until after the recommendations are reviewed.

Table 3-15 Ranking of Proposed Best Management Practices for the Barker Slough Watershed

BMP	Primary Removal (DOC or Sediment)	Cost Effectiveness	Technical Feasibility	Implementation Feasibility	Long Term Reliability
Off-Channel Stock Watering	Both	H	H	H	M
Installation of Fencing to Mid-Point of the Watershed	Both	H	H	M	L
Installation of Fencing from Mid-Point of the Watershed to the Pumping Plant	Both	H	H	H	L
Lay Back Slopes and Revegetate	Sediment	L	H	M	M
Control of Tailwater	DOC	H	H	L	L
Restoration of Channel above Campbell Lake	Sediment	M	M	M	H
Noonan Drain Wetland Creation	Sediment	L	M	L	M
Campbell Lake Low Water Bypass	DOC	H	H	M	H
Spillway Canal to Calhoun Cut	Both	L	H	L	M
Campbell Lake Flow Management	Both	H	H	L	M
Concrete Lining of Noonan Main Drain	Both	L	H	M	H
Stormwater Detention	Sediment	L	M	L	M
Urban Runoff Erosion Control	Sediment	H	H	M	M
Vegetative Filter Strips	Sediment	M	M	L	L
Winter Wheat Early Planting	Sediment	M	H	L	L
Conversion of Annual Cropland	Sediment	H	H	L	M
Elimination of Late Season Irrigation	DOC	H	H	L	L
Create Retention Storage	DOC	H	H	L	L
Deep Ripping	DOC	M	M	M	L
Gypsum Treatment	Both	M	M	H	H
Campbell Ranch Erosion Control	Sediment	H	H	M	L

Note: H = High; M = Medium; L = Low
Technical Feasibility = feasibility based on physical aspects of implementation
Implementation Feasibility = willingness of landowners to adopt a BMP

References

LITERATURE CITED

Barbor MG, Major J. 1977. *Terrestrial vegetation of California*. California Native Plant Society.

Bates LA, Dollarhide WE, Kliewer GF, Staidl GJ, Goudy CB. 1977 May. *Soil survey of Solano County, California*. US Department of Agriculture, Soil Conservation Service in cooperation with UC Agricultural Experimental Station.

California. 1977. *Geologic Map of California*. Jennings CW, compiler. California Department of Conservation, color, scale 1:750,000.

[DPR] California Department of Pesticide Regulation. 1999 May. *Summary of pesticide use report data 1996*.

[DPR] California Department of Pesticide Regulation. 1999a Jun. *Summary of pesticide use report data 1997*.

[DPR] California Department of Pesticide Regulation. 2000 Feb. *Summary of pesticide use report data 1998*.

[DWR] California Department of Water Resources. 1994 Mar. *Historical ground water levels in Solano County*.

[DWR] California Department of Water Resources, Division of Local Assistance, Water Quality Assessment Branch. 1996 May. *California State Water Project sanitary survey update report 1996*.

[DWR] California Department of Water Resources. 1996a. *The North Bay Aqueduct*. Office of Water Education.

[DWR] California Department of Water Resources. 1998 Jul. *The North Bay Aqueduct Barker Slough watershed water quality, phase I report*.

[DWR] California Department of Water Resources, Division of Operations and Maintenance, Water Quality Section. 1999 Sep. *Water quality assessment of the State Water Project, 1996-1997*.

[DWR] California Department of Water Resources. 2000 Apr. *California State Water Project contractors*.

[DWR] California Department of Water Resources, Division of Operations and Maintenance, Water Quality Section. 2000a Jul. *Water quality assessment of the State Water Project, 1998-1999*.

[EPA] US Environmental Protection Agency. 1998. "National primary drinking water regulations: disinfectants and disinfection byproducts." *Federal Register* 63, no. 241 (16 Dec): 69390.

Farm Chemicals Handbook. 1994. Willoughby (OH): Meisters Publishing Co. Vol. 8.

Fleege, Niles, North Bay Regional Water Treatment Plant. 18 Jul 2000. "Regarding: Treatment plant data associated with treating the NBA data." Memo to North Bay Aqueduct Watershed Committee. (see author also under Personal Communications)

Geier and Geier Consulting, Inc. 1994 Jul. *Draft environmental impact report, Campbell Ranch use permit application nr U-92-16*.

Goldberg S, Lebron I, Suarez DL. 2000. "Soil colloidal behavior." In: Sumner ME, editor. *Handbook of Soil Science*. New York: CRC Press. Chapter 6

Hydro Science. 2000 Dec. *Solano County Water Agency North Bay Aqueduct, Barker Slough draft watershed water quality improvement plan*.

Jepson Prairie Docent Program. 1998. "Jepson Prairie Preserve. A native perennial grassland and vernal pool habitat."

Olson, ME, Goh J, Phillips M, Guselle N, McAssister TA. 1999. "*Giardia* cyst and c*ryptosporidium oocyst* survival in water, soil, and cattle feces." *J Envirol Qual*
(28):1991-6.

Shainberg, I, Singer MJ. 1990. "Soil responses to saline and sodic conditions." In: Tanjii KK, editor. *Agricultural salinity assessment and management.* New York:ASCE Manuals and Reports on Engineering Practice nr 71.

Singer MJ. 1999. "Best management practices for control of organic carbon and suspended solids in a water supply watershed." Proposal submitted to UC Davis, Water Resources Center.

Sposito, G. 1989. *The chemistry of soils*. New York: Oxford University Press.

US Salinity Laboratory Staff. 1954. "Diagnosis and improvement of saline and alkali soils." Agriculture Handbook 60.

PERSONAL COMMUNICATIONS

Bartkowiak, Donna, Department of Pesticide Regulation. 2000. E-mail to Carol DiGiorgio, DWR. Aug 15.

Bell, Jeffrey, Solano County Department of Environmental Management, Technical Services. 2000. Phone conversation with Carol DiGiorgio, DWR. May 16.

De Albidress, Laura North Bay Regional Water Treatment Plant. 2000. Letter to Carol DiGiorgio, DWR. Dec 21.

DaMassa, Lenny, Solano County Department of Agriculture. 2000. Phone conversation with Carol DiGiorgio, DWR. Aug 1.

Eubanks, David, Solano County Department of Environmental Management, Hazardous Materials. 2000. Phone conversation with Carol DiGiorgio, DWR. May 19.

Fleege, Niles, North Bay Regional Water Treatment Plant. 2000a. Phone conversation with Carol DiGiorgio, DWR. May 19. (see also Reference list)

Fleege, Niles, North Bay Regional Water Treatment Plant. 2000b. Phone conversation with Carol DiGiorgio, DWR. Aug 4.

Fleege, Niles, North Bay Regional Water Treatment Plant. 2000c. E-mail to Carol DiGiorgio, DWR. Dec 15.

Gage, Richard, DWR, Division of Operations and Maintenance, Delta Field Division. 2000. Phone conversation with Carol DiGiorgio, DWR. May 12.

Gage, Richard, DWR, Division of Operations and Maintenance, Delta Field Division. 2000a. Phone conversation with Carol DiGiorgio, DWR. Jul 31.

Gage, Richard, DWR, Division of Operations and Maintenance, Delta Field Division. 2000b. E-mail to Carol DiGiorgio, DWR. Dec 15.

Goldbronn, Joe, Superintendent, Cypress Lakes Golf Club. 2000. Phone conversation with Carol DiGiorgio, DWR. Dec 15.

Joyce, Debbie, General Manager, Cypress Lakes Golf Club. 2000. Phone conversation with Carol DiGiorgio, DWR. Dec 15.

Kimball, Charlotte, Hydro Science. 2000. E-mail Carol DiGiorgio, DWR. Oct 18.

Kimball, Charlotte, Hydro Science. 2000a. Phone conversation with Carol DiGiorgio, DWR. Dec 12.

Kimball, Charlotte, Hydro Science. 2000b. Phone conversation with Carol DiGiorgio, DWR. Dec 18.

McCall, Jackie, City of Vacaville. 2000. E-mail to Carol DiGiorgio, DWR. Dec 20.

McCune, Bill, DWR. 2000. Conversation with Carol DiGiorgio, DWR. Dec 15.

Monske, Chris, Solano County Department of Environmental Management, Planning Services. 2000. Phone conversation with Carol DiGiorgio, DWR. May 16.

Morris, Frank, Solano County Water Agency. 2000. Phone conversation with Carol DiGiorgio, DWR. Jun 6.

Morris, Frank, Solano County Water Agency. 2000a. Fax to Carol DiGiorgio, DWR. Jun 14.

Parker, Brian, Solano County Department of Environmental Management, Planning Services. 2000. Phone conversation with Carol DiGiorgio, DWR. Aug 3.

Parker, Brian, Solano County Department of Environmental Management, Planning Services. 2000a. Phone conversation with Carol DiGiorgio, DWR. Dec 15.

Ramadan, Turan, Water Operations Supervisor, City of Napa. 2000. E-mail to Carol DiGiorgio, DWR. Dec 1.

Rice, Anne, City of Vallejo, Fleming Hill Water Treatment Plant. 2000. Fax to Carol DiGiorgio, DWR. Dec 4.

Rice, Anne, City of Vallejo, Fleming Hill Water Treatment Plant. 2000a. E-mail to Carol DiGiorgio, DWR. Dec 27.

Schmidtbauer, Terry, Solano County Department of Environmental Management, Technical Services. 2000. Phone conversation with Carol DiGiorgio, DWR. May 12.

Scribner, Jim, Solano Irrigation District. 2000. Phone conversation with Carol DiGiorgio, DWR. May 12.

Singer, Michael, UC Davis. 1999. Department of Land, Air, and Water Resources. Meeting. Aug 14.

Vale, Mark, Solano Irrigation District. 2000. Phone conversation with Carol DiGiorgio, DWR. Aug 3.

Vale, Mark, Solano Irrigation District. 2000a. Phone conversation with Carol DiGiorgio, DWR. Dec 20.

Walker, Leah, Department of Health Services. 2000. E-mail to Carol DiGiorgio, DWR. Nov 17.